Predicting National Football League game outcomes: A machine learning approach

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UXCFXK-30-3

Digital Systems Project



# Abstract

This project presents the development and evaluation of an innovative system designed to predict the outcomes of National Football League (NFL) games using advanced machine learning techniques. At the core of this project is the creation of a robust predictive model that leverages historical NFL game data, ranging from the year 2000 to the present, to forecast game outcomes with a high degree of accuracy. Utilizing a comprehensive dataset, the system preprocesses this information to suit the needs of a machine learning model, which then applies analytical techniques to identify patterns and make predictions based on historical performance.

A key feature of the project is the development of a user-friendly graphical user interface (GUI), implemented using PyQt, that enables users to interact with the system efficiently. This interface allows users to select teams and view predicted outcomes, enhancing the accessibility and usability of the predictive system. Functional requirements such as data importation, preprocessing, and predictive modelling, along with non-functional requirements including performance, usability, and scalability, have been meticulously defined to ensure the system’s effectiveness and reliability.

The methodology adopted for this project is based on the Kanban agile framework, chosen for its flexibility and efficacy in managing iterative development processes. This approach facilitated a dynamic and responsive development environment, allowing for continuous refinement of the predictive model and the GUI. Evaluation of the system demonstrates its capability to achieve a prediction accuracy score exceeding the initial objective of 60%, signifying a notable advancement in the field of sports analytics. This project not only contributes to the technological landscape of sports prediction but also bridges the gap between sports enthusiasts and data-driven insights, empowering users with a tool that enhances their understanding and engagement with NFL game outcomes.

Through the integration of machine learning, agile methodology, and user-centred design, this dissertation underscores the potential of data-driven approaches in transforming sports analytics. The NFL Predictor program exemplifies the application of theoretical knowledge to practical challenges, offering a comprehensive solution that is both innovative and grounded in rigorous research.

Insert results and paragraph here.

Insert conclusions here..

Insert keywords here..

# Acknowledgements

A heartfelt thank you to the National Football League (NFL) for igniting my passion and inspiring this project with their captivating and dynamic sport.

To my other half, Lily, your endless belief, and support in my darkest times have been my greatest strength.

Lastly, this project is dedicated to my son Ezra, who has been the driving force behind every effort and achievement.

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# Introduction

In the ever-evolving landscape of sports analytics, the combination of machine learning and sports data has paved the way for groundbreaking advancements. In American Football, a sport well known for its complexity and unpredictability, the ability to foresee game outcomes has immense implications for enthusiasts, analysts, and the betting industry.  “Predicting National Football League game outcomes: A machine learning approach” examines this exciting realm by employing machine learning algorithms to forecast the results of NFL games.

*Project Overview*

The core of this project lies in the creation of a robust machine learning model. This model will be meticulously trained using comprehensive NFL team statistics from the year 2000 to the present day via Application Programming Interface or API for short. The primary objective is to craft an accurate predictive algorithm, capable of forecasting game outcomes based on intricate patterns and statistical insights derived from years of NFL gameplay. To enhance user accessibility and interaction, a user-friendly application will be developed using PyQT, allowing users to conveniently select home and away teams, and receive predictions from the machine learning model.

*Aims and Objectives*

The aim of this project is to bridge the gap between sports enthusiasts and data-driven insights, empowering users with the ability to make informed predictions about NFL game results. The specific objectives include:

* Development of User-Friendly Interface: Create an intuitive application using PyQT that facilitates user interaction, enabling seamless selection of NFL teams for prediction analysis. This interface will serve as a gateway for users to access the power of machine learning in predicting game results.
* Machine Learning Algorithm Implementations: Utilise advanced machine learning techniques to process and analyse the extensive NFL team statistics. The model will be trained meticulously, leveraging data from 2000 to the present, ensuring its capability to recognise nuanced patterns and trends within the game.
* Data Gathering and Integration: The integration of this extensive data will be fundamental in enhancing the model’s predictive accuracy.
* Prediction Accuracy: Strive to achieve a prediction accuracy score of 60% or better, signifying a significant advancement in the world of NFL game forecasting. This accuracy benchmark serves as a quantitative measure of this model’s reliability and effectiveness.

This project represents a dynamic fusion of sports passion and cutting-edge technology. By seamlessly integrating data acquisition, advanced machine learning techniques, and user-friendly interface design, this endeavour aims to redefine how we perceive and engage with the world of sports predictions. More than just a prediction tool, it stands as a testament to the transformative power of data-driven insights in the land of sports. The project not only enhances the experience of NFL enthusiasts but also contributes to the broader landscape of predictive analytics.

# Literature Review

*Introduction*

The pursuit of a deeper understanding of predictive dynamics within the NFL forms the cornerstone of this research. This literature review navigates through the intricate web of methodologies and theoretical frameworks that underpin predictive analysis in sports. Beyond the surface-level application of machine learning, it delves into the nuanced realms where data, technology, and sports intersect. The review critically assesses the evolution of predictive tools, not just as statistical models but as entities influenced by advancements in data processing and user experience design. It also explores the broader implications of predictive accuracy, addressing the balance between algorithmic precision and the inherently unpredictable nature of sports. By threading through these various dimensions, the review establishes a comprehensive backdrop against which this research is positioned, highlighting its unique contribution in enhancing understanding and application within the field.

*Historical Context*

In the historical tapestry of sports analytics, the seminal works of Lapham and Bartlett in 1995 [1] and Anderson in the same year [2] serve as foundational pillars in integrating artificial intelligence with sports performance. Lapham and Bartlett notably explored the application of expert systems in sports biometrics, a novel approach at the time that paved the way for more sophisticated AI-driven methods. Meanwhile, Anderson's exploration of Artificial Neural Networks (ANNs) began to redefine the landscape of sports analytics, suggesting a future where complex algorithms would become integral to sports analysis.

This intersection of AI and sports analytics gained significant momentum in 2006 with Bartlett's foresight [3]. His projection that multilayer ANNs, which are now recognised as a core component of deep learning, would play a critical role in sports technique analysis, has proven prescient. These advanced forms of ANNs have since evolved into a dominant force in sports analytics, largely due to their ability to handle complex, multi-dimensional data sets with unprecedented efficiency and accuracy. The convergence of computer science and sports analytics during this period was further accelerated by significant advancements in computer hardware [4]. This era witnessed a substantial improvement in computational capabilities, enabling the processing of large-scale data sets and the execution of intricate models that were previously unfeasible. The release of large data sets to the public domain also played a crucial role, fostering a synergistic relationship between machine learning and sports analytics. This popularisation of data not only made advanced analytical techniques more accessible but also encouraged a broader adoption and innovation in the field.

This historical journey marks a transformative period in sports analytics, where traditional methods were supplanted by more advanced, AI-driven approaches. The pioneering works of Lapham, Bartlett, and Anderson laid the groundwork for this revolution, demonstrating the untapped potential of AI in enhancing sports performance analysis and strategy formulation. These developments collectively signify a pivotal shift in the field, one that has fundamentally altered the way sports performance is analysed and optimised.

*Machine Learning in Sports Analytics*

The integration of machine learning (ML) into sports analytics represents a paradigm shift in how data is utilised to enhance athletic performance, strategy formulation, and predictive accuracy. This transition marks a significant departure from traditional statistical methods, embracing more sophisticated, data-driven approaches capable of handling the complexity and dynamism inherent in sports. The advent of ML in sports analytics has not only refined predictive modelling but also revolutionised the way teams and players are analysed and managed. In team sports in particular, the power of prediction that machine learning brings, has opened new streams for understanding of game fluctuations and outcomes. Use of various algorithms has demonstrated remarkable potential in forecasting game results, player performance and even injury risk.

Purucker’s “Neural network quarterbacking” (1996)[5] explores the implementation of supervised and unsupervised training for NFL game outcome prediction. The study delves into a range of neural network strategies, including hamming networks, adaptive resonance theory(ART), Kohonen self-organising maps and back-propagation (BP) networks. Purucker highlights, *"The neural networks, trained on these data sets, then provided the basis for developing a predictive model for NFL game outcomes"*[6]​. This investigation is critical in understanding how different neural network architectures and training paradigms can be optimised for sports analytics, particularly in predicting the outcomes of NFL games. By comparing these methods, the study sheds light on their respective efficacies and limitations, offering valuable insights into the practical application of neural networks in sports prediction contexts.

In their exploration of machine learning processes in sports analytics, Ulf Brefeld et al.(2022)[7] present a methodology that balances the practical constraints of data availability with the need for robust analytical models. One of the commendable aspects of their work is the intentional simplicity of their model design. This approach, aimed at avoiding overfitting and ensuring robustness, is particularly apt given the limited data available to them. Their goal was not to achieve perfect accuracy but to provide general insights into the effects of variables across different leagues, a decision that demonstrates a practical and adaptable approach in the context of varied and limited datasets​​.

However, this simplicity and focus on robustness come with certain limitations. Notably, there is a compromise on the accuracy of their models. *“Our models are quite simplistic as we have sacrificed some of the accuracy to prevent possible overfitting and obtain robust models that could provide some general insights into how the effect of variables changes based on league”*[8]. By opting for simpler models, the authors accept a reduction in precision, acknowledging that their approach might not capture the full complexity or subtleties that a more sophisticated model could. Additionally, the simplification of the models limits the depth of analysis regarding the individual weights and effects of each parameter on the goal probability. In contrast to state-of-the-art models in sports analytics, which often incorporate numerous features and complex structures, the authors' approach might not provide as detailed insights into specific parameter dynamics.

The work of Brefeld et al. thus illustrates a key challenge in sports analytics: balancing the depth and complexity of analysis with the practicalities of data availability and model robustness. Their approach highlights both the strengths and limitations inherent in applying machine learning in this field, especially under constraints of varying data quality and quantity. This balance is crucial in sports analytics, where the diversity of data across different contexts necessitates a flexible and pragmatic approach to model design and implementation

Horvat et al.(2022) work on machine learning in sports analytics titled “The use of machine learning in sport outcome prediction: A review”[9], a strength of their study is the comprehensive approach towards various machine learning algorithms in sports analytics. Horvat et al. delve into the complexities of these methodologies, providing a nuanced understanding that is beneficial for those looking to grasp the diverse applications of machine learning in sports. Their work is particularly insightful in discussing the effectiveness of Decision trees and Random Forest models in the context of NFL predictions, noting the higher percentages of accuracy achieved with these methods. This specific insight into the NFL is invaluable, as it not only highlights the effectiveness of certain models but also underscores the potential of machine learning in refining predictive analysis in specific sports domains.

Furthermore, the clarity in their exposition of complex machine learning concepts makes their piece accessible to a broad audience. This aspect of their work is crucial in making the intricate world of machine learning in sports analytics comprehensible to those outside the field, thereby expanding its reach and impact. Another positive aspect highlighted in the Horvat and Job study is the detailed comparison of predictive accuracies across different sports using various machine learning models. Notably, in the context of Football (NFL), Decision Trees and Random Forest models are shown to have a higher predictive accuracy (82.18%) compared to other techniques like Neural Networks, Support Vector Machines (SVM), and Naive Bayes, as demonstrated in Figure 11 on page 19[10] of their work. This empirical evidence underscores the effectiveness of ensemble methods in sports predictions and specifically in the realm of NFL game outcomes, however, the piece does have its limitations.

In the paper “Machine learning for sports betting: should predictive models be optimised for accuracy or calibration?” by Walsh et al. [11] while the theoretical discussion of machine learning techniques is robust, the document could benefit from a deeper exploration into the practical applications of these models. The inclusion of comprehensive case studies would provide more tangible insights into the efficacy of these predictive models in real-world scenarios. Moreover, there is a noticeable gap in the critical examination of model limitations and overfitting, especially given the varying data volumes and qualities across different sports. “We hypothesised that accuracy is not the most appropriate metric to evaluate the performance of the predictive model” [12]. A more balanced discussion that also scrutinises the potential pitfalls or challenges in applying these models would offer a more nuanced perspective on the subject.

In their investigation into the application of machine learning models for NFL prediction accuracy, Bunker et al. offer a robust analysis that brings to light both the advances and the areas in need of improvement within the domain of sports prediction. The authors detail the rise in the application of Artificial Neural Networks (ANNs) in sports result prediction, especially as the sole predictive model. Their exploration prompts a critical evaluation of whether "ANNs have performed better than other models in practice"[13]​​, especially with the advent of deep learning technologies. This highlights the evolving nature of machine learning applications in sports and the necessity for continuous reassessment of the effectiveness of various predictive models.

Moreover, Bunker et al. recognise the value of interpretable models, such as Decision Trees, in sports analytics. These models not only facilitate prediction but also assist in "the identification of the most important performance indicator variables that influence match results"[14]​​, which is valuable in terms of developing appropriate strategies and focus areas. Their findings illustrate that such models have contributed to some of the highest accuracy results in American Football, underscoring the practical benefits of these algorithms in strategic sports analysis: "American Football and Basketball reporting their highest accuracy results using CART and Logistic Model Trees (LMT) respectively"[15]​​.

The research by Bunker et al. does not come without its drawbacks. A limitation is found in the reliance on historical data which may not always capture the full dynamics of the sport due to changes in teams, players, and strategies over time. This reliance can lead to models that may not fully adapt to the evolving nature of the games they aim to predict. While the study brings attention to the successes of particular machine learning models, it also alludes to a potential overemphasis on ANNs, despite evidence suggesting that they do not always outperform other algorithms. The critical insight here is the need for diversified approaches and comparisons across a range of machine learning techniques to ensure the most effective model is utilised for prediction.

While the work of Bunker et al. contributes significantly to the discourse on predictive accuracy in NFL games, it also highlights the need for a diverse application of models and a critical examination of historical data's role in shaping predictive outcomes. Their findings, particularly as encapsulated in Table 2[16], provide a valuable benchmark for assessing the performance of various machine learning models in sports analytics.

*Integrating Usability, Ethics, and Innovation in Sports Analytics*

The integration of machine learning algorithms into user interfaces presents a unique intersection of technical sophistication and user accessibility. The study by Bernardo et al. (2017)[17] underlines the importance of user interaction with intelligent systems, highlighting that such interaction should not be limited to scenarios where the software's intelligence is "baked in." Instead, they advocate for interactive machine learning (IML) approaches, which allow end-users to create and customise systems, thereby significantly enhancing the user experience​​.

This user-centric approach to machine learning system design is invaluable, as it ensures that the final product is not just a reflection of the developers' abilities, but also an embodiment of the users' needs and preferences. By involving end-users in the training and configuration of learning algorithms and their interfaces, the systems become more tailored and intuitive for those who will ultimately use them. However, the paper also implies that while IML approaches can enhance user experiences, they may introduce complexities in understanding and managing the system for those without a background in machine learning. The risk here is that the learning curve associated with these systems could deter users from fully utilising their capabilities, potentially undermining the very user experience they aim to enhance.

Moreover, the paper suggests that a balance must be struck between user empowerment and system complexity. As machine learning systems become more accessible, there is a need for robust support and guidance to ensure that users can effectively engage with the system without becoming overwhelmed by its intricacies. The research emphasises that the design of interfaces for machine learning systems must prioritise clarity and ease of use to prevent users from being alienated by the complexity of the algorithms at work. Bernardo et al. (2017) point out that the success of these systems depends largely on the ability to translate advanced machine learning concepts into user-friendly tools that provide actionable insights without exposing the user to the underlying complexities. As such, designers and developers must work collaboratively with end-users to identify the most relevant features and controls that should be available, ensuring that the system remains both powerful and accessible. This participatory design approach not only facilitates greater user adoption but also fosters an environment where machine learning tools can be used effectively to support decision-making processes across various domains. Through this lens, the study contributes to a growing body of literature that seeks to demystify machine learning, advocating for interfaces that empower users rather than confound them.

In the examination of the paper by Drabiak et al. (2023)[18], the ethical considerations of AI and machine learning (ML) emerge as a dual-edged sword in the context of technological advancement and its application in predictive projects, such as those involving PyQT for NFL outcomes.  The paper draws attention to the ethical challenges, particularly the "bias in the training process and lack of prediction transparency"[19]​​. These issues are not merely technical but also hold significant societal implications, impacting the fairness and trustworthiness of predictive modelling. Drabiak et al. highlight the reported failures in AI, often linked to societal constructs like "gender and race"​​[20], which resonates with the critical need for ethical vigilance in machine learning projects. Such biases, if unaddressed, could skew the predictive outcomes in NFL predictions, leading to ethical dilemmas, especially if the predictions are utilised in real-world betting or team strategies.

One crucial takeaway from their work is the call for "more explainable/interpretable AI algorithms" which would enhance "transparency, oversight, and accountability"[21]​​. For a project that aims to predict NFL outcomes, incorporating these ethical considerations into the design of machine learning models is not just a matter of regulatory compliance but a foundational aspect that could determine its long-term viability and acceptance by the user community.  However, Drabiak et al. also discuss the "irreproducible and conflicting results"[22]​​ in literature stemming from these ethical complexities. This serves as a cautionary note for predictive projects, where the replicability of results is paramount to their credibility.

While the ethical framework outlined by Drabiak et al. can serve as a beacon for responsible AI development in sports analytics, it also poses a challenge. Implementing a user-friendly interface that aligns with these ethical guidelines requires a careful balance between user accessibility and the rigorous demands of ethical AI. For the project at hand, this could mean creating a transparent system where users are aware of how predictions are made, ensuring the project benefits from AI's capabilities while upholding the highest ethical standards.

*Conclusion*

In light of the comprehensive review conducted, the groundwork for the subsequent requirements analysis of the project is well-established. It meticulously traces the historical evolution of predictive analytics, demonstrating the ever-increasing integration of machine learning techniques into sports analytics. Emphasises the critical need for a balanced approach in model design, considering both complexity and data availability. The review also sheds light on the strengths and limitations of various machine learning models, offering valuable insights into their applicability within the context of NFL game outcome prediction. This knowledge is crucial as it provides a basis for informed decision-making when selecting the most suitable algorithms for the project.

The review touches upon the importance of usability and innovation in sports analytics, particularly in the design of user-friendly interfaces for machine learning systems. This insight underscores the need to align the project's requirements with user-centric design principles, ensuring that the end-product empowers users while remaining accessible and transparent. Ethical considerations raised in the review prompt a critical examination of how the project's predictive models adhere to ethical guidelines, particularly in terms of transparency and fairness. These ethical insights serve as a compass, guiding the project's requirements towards responsible AI development and the establishment of trustworthiness.

In essence, the review acts as a bridge between the historical context and current trends in predictive analytics within the NFL, providing a robust foundation for the forthcoming requirements analysis. It offers a wealth of insights, guiding the project towards well-informed decisions regarding data sources, model selection, user interface design, and ethical considerations, thereby ensuring a comprehensive and informed approach to the project's requirements.

# Requirements

By outlining clear, measurable, and achievable functional and non-functional requirements, this segment establishes the foundational criteria against which the project's development and success will be evaluated. The requirements are meticulously crafted, ensuring they are deeply rooted in the research findings and align with the project's overarching goals. Each requirement has been carefully selected to contribute significantly to the project's functionality and performance, guaranteeing that both the operational needs and the broader research objectives are met. This section is essential in guiding the development process and ensuring that the final outcome is not only technically sound but also aligns with the theoretical framework and practical implications.

*Functional Requirements*

F1. Data Import Functionality: This requirement stipulates that the system must possess the capability to import and process historical NFL game data. This is essential for ensuring that the prediction model has access to relevant and comprehensive datasets, which are the foundation for accurate predictions.

F2. Data Preprocessing: The system is required to automatically preprocess the data to align with the machine learning model's needs. This involves cleaning, normalising, and transforming the data into a format suitable for analysis, which is a critical step for effective model training.

F3. Predictive Modelling: The implementation of a machine learning algorithm to predict NFL game outcomes is a core functionality. This requires the system to utilise advanced analytical techniques to interpret data and make future game predictions based on historical patterns.

F4. User Interface: Provision of a graphical user interface is necessary for facilitating user interaction with the system. The interface should be intuitive and user-friendly, allowing users to easily navigate and utilise the application's features.

F5. Team Selection: This functionality allows users to select specific NFL teams for which they wish to predict outcomes. It provides a customisable user experience by enabling choices that are tailored to the user’s interests.

F6. Prediction Execution: The system must be able to generate predictions based on user input and subsequently display these results. This involves processing the selected inputs through the prediction model and presenting the outcomes in an understandable format.

F7. Model Training: Including functionality for re-training the model with updated data is essential for maintaining the accuracy and relevance of predictions. This allows the system to adapt to new data patterns and changes in team performance over time.

F8. Error Handling: Error handling is crucial for ensuring the system's robustness. It should be capable of identifying, reporting, and managing errors in data processing or during the prediction phase, thereby enhancing reliability and user trust.

F9. Data Visualization: Integrating data visualisations, such as team performance graphs, is required to enhance the analytical capabilities of the system. Utilising libraries like Matplotlib or Seaborn, this feature allows for more intuitive and insightful presentation of data.

F10. Help and Documentation: Providing in-app guidance or documentation is crucial for user support. This includes instructions on how to use the application and information about its features, ensuring that users can effectively engage with and understand the application.

*Non-Functional Requirements*

N.F.1 Performance: The system is required to perform predictions within a reasonable time frame. This ensures efficiency and enhances user experience, as users expect quick responses from predictive applications.

N.F.2 Usability: It's imperative that the GUI is user-friendly and intuitive. This aspect focuses on ease of use, ensuring that users can navigate and operate the application without difficulty, irrespective of their technical expertise.

N.F.3 Scalability: The system must be capable of handling increasing volumes of data without significant degradation in performance. This is crucial for maintaining efficiency as the dataset grows over time.

N.F.4 Reliability: The prediction model should consistently provide accurate results. This reliability is vital for user trust and the application's credibility, especially in a field as dynamic as NFL game predictions.

N.F.5. Maintainability: The code of the system should be well-documented and easy to maintain. This facilitates future updates and modifications, ensuring the application remains functional and relevant over time.

N.F.6. Security: Ensuring data privacy and protecting against unauthorised access is a critical requirement. This encompasses safeguarding user data and the integrity of the application from external threats.

N.F.7. Compatibility: The application should function seamlessly on standard operating systems such as Windows and macOS. This broadens the application's accessibility to a wider user base.

N.F.8. Efficiency: Optimising resource usage, including memory and CPU, during data processing and prediction, is crucial. This ensures the application runs smoothly without overburdening the user's device.

N.F.9. Accessibility: The GUI must be accessible to users with disabilities. This involves designing the interface in a way that is usable for people with a range of abilities, ensuring inclusivity.

N.F.10. Aesthetics: The application should possess a professional and appealing visual design. This enhances user engagement and reflects the quality of the application, making it more attractive to users.

*Conclusion*

This section has meticulously outlined the essential functional and non-functional aspects necessary for the successful development and operation of the NFL predictor program. These requirements, rooted in extensive research and aligned with the project's objectives, provide a clear roadmap for development. They ensure that the end product is not only technically sound but also meets user expectations and adheres to industry standards. This comprehensive approach guarantees that the predictor system will be robust, user-friendly, and effective in its application, forming the cornerstone of a successful project that aligns with both theoretical and practical considerations

# Methodology

The development of the NFL Predictor program embraced the Kanban methodology, chosen for its agility and adaptability to the fluid nature of software development projects. Unlike traditional, linear approaches to project management, Kanban’s flexible system is particularly advantageous for managing dynamic and iterative processes, such as those encountered in this project.

A screenshot of a computer

Description automatically generatedThe Kanban methodology, with its principles of visualizing work, limiting work in progress, managing flow, making policies explicit, and utilizing feedback loops, is ideally suited to the evolving nature of software development. Its selection was predicated on the need for a methodology that could accommodate the iterative refinement of machine learning models and the user interface, ensuring that each project component was developed to its fullest potential.

At the core of project management was the Kanban board, a visual tool that depicted the workflow across stages such as data collection, preprocessing, model development, and GUI design. This visualisation was not only instrumental in clarifying the current status of work but also in identifying areas that required immediate attention. The board was structured into columns that reflected key development phases, from 'Backlog' to 'In Progress,' 'Testing,' and finally, 'Done,' facilitating a clear pathway for task progression.

By capping the number of tasks in progress simultaneously, the Kanban methodology fostered focused advancement and minimized bottlenecks. This limit ensured a dedicated effort on each task, enhancing the quality and efficiency of work. Managing the flow of tasks involved continual monitoring and adjustments, addressing any delays or obstacles to maintain a steady and efficient workflow.

Given the solo nature of this project, feedback loops were internally driven, relying on self-review and assessments against project objectives and milestones. Regular reflection on the progress and quality of outputs enabled a responsive approach to development, incorporating insights and learning into subsequent iterations. This iterative process was crucial for refining the project's direction and for implementing enhancements to the predictive model and GUI.

Adapting to changing priorities and maintaining effective self-communication presented challenges. These were mitigated through disciplined scheduling and setting clear, achievable objectives for each development phase. Digital tools such as Trello facilitated task tracking and organisation, serving as a virtual extension of the Kanban board, and ensuring that the project remained aligned with its evolving needs.

A Gantt chart complemented the Kanban board by outlining the project timeline, key milestones, and phases. Despite Kanban’s emphasis on continuous flow, the Gantt chart provided a macro view of the project's timeline, ensuring adherence to deadlines and facilitating the anticipation of future tasks.

A screenshot of a computer

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The application of the Kanban methodology to the development of the NFL Predictor has underscored the importance of flexibility and responsiveness in managing complex software projects. Through visual management, continuous adaptation, and iterative refinements, the methodology has successfully navigated the complexities of creating a sophisticated predictive model. While challenges in managing changing priorities were encountered, the structured yet flexible approach of Kanban, coupled with the strategic use of a Gantt chart, ensured a focused progression towards the project's goals. This solo endeavour, from conception to completion, exemplifies the efficacy of an agile and iterative process in achieving a user-friendly and efficient predictive tool for NFL game outcomes.

# Design

This chapter delves into the detailed design phase of the NFL predictor program, a critical stage where theoretical concepts and requirements are translated into a functional system architecture. The design process is pivotal in laying the groundwork for the development and eventual success of the application. It involves meticulously planning and conceptualising the various components and interactions within the system to ensure that the final product is robust, efficient, and user-friendly.

Central to this process are several key design diagrams, each serving a unique purpose in illustrating different aspects of the system. The use case diagram, for instance, is instrumental in depicting the system's functionality from the user's perspective, highlighting how different users will interact with the application. Meanwhile, the flow diagram provides a bird's-eye view of the system's process flow, detailing how data is input, processed, and output. The sequence diagram plays a crucial role in mapping out the interactions between various objects within the system over time, particularly during the prediction process. Test design is fundamental in ensuring that each component of the system functions as intended and interacts seamlessly with others. It is a testament to the system’s reliability and effectiveness in real-world scenarios

The diagrams not only serve as a blueprint for development but also as a communication tool, bridging the gap between conceptualisation and implementation. They are the visual representations of the system’s architecture, encompassing its functionalities, processes, and interactions, thereby laying a solid foundation for the subsequent development phase.

A machine learning pipeline diagram offers a visual representation of the process through which data progresses from initial collection to the generation of predictions by a model. This diagram plays a crucial role in outlining the sequential steps necessary for converting raw data into valuable predictions or insights. Its significance is especially noted in the domain of machine learning, providing a clear framework for the stages of data processing and model training. The pipeline aids in comprehending the chronological and logical flow of data across various stages of transformation and analysis, ensuring each phase is thoughtfully crafted and implemented to boost the final model's accuracy and efficiency.

A diagram of a company

Description automatically generated with medium confidence

The pipeline initiates with 'User Interaction', marking the beginning of the prediction process. This is followed by the 'Team Selection' phase, where the user inputs their choices, usually selecting teams for analysis or prediction.

Subsequently, 'Data Importing' takes place, involving the collection and integration of relevant historical information such as past match statistics, player performance metrics, and team rankings into the system. The depth and quality of this data are pivotal in determining the prediction's trustworthiness. The 'Data Preprocessing' stage then follows, where the raw data undergoes cleaning, normalisation, and transformation to make it suitable for analysis. This step might cover rectifying missing values, encoding categorical variables, scaling numerical data, and applying time-series transformations for sequential data.

At this point, the pipeline diverges into two parallel processes: 'Covariate Analysis' and 'Dimensionality Reduction'. 'Covariate Analysis' examines variables that could affect the prediction outcome, aiming to decipher relationships and possible causality within the data. Concurrently, 'Dimensionality Reduction' focuses on simplifying the model by minimising the number of variables under consideration, to reduce redundancy or concentrate on crucial variables. 'Feature Engineering', building on preprocessing, involves the creation of new features from existing data to bolster model performance, incorporating domain expertise to unveil more impactful features that could elevate the model's predictive capability.

During 'Model Training', the prepared dataset is applied to a machine learning algorithm, which learns from the data by identifying patterns and developing a model encapsulating these insights. The 'Prediction' phase sees the application of the trained model to new or unseen data to generate forecasts, leveraging the knowledge acquired during training to predict outcomes for the specified scenarios. The process culminates in 'Displaying Results', where the predictions are presented to the user in formats like visualisations, tables, or reports, showcasing the actionable insights derived from the model.

This machine learning pipeline diagram acts as a guide, clarifying the step-by-step data and object interactions within a system. It enhances transparency in the machine learning process and identifies key points for optimisation to improve the model's predictive accuracy.

In the field of software engineering, the sequence diagram emerges as a pivotal instrument, crafted to illustrate the chronological interactions between various entities or objects in a system. Its foremost purpose is to visualise the timing of object interactions, thus enabling a lucid depiction of the flow of control and data dynamically. The diagram clarifies the order in which messages are exchanged among objects, aiding in pinpointing possible inefficiencies or bottlenecks within the interaction process. By delineating the flow of messages, it assists in ensuring that different system components remain cohesive and synchronised, ultimately contributing to the system's enhanced efficiency and robustness.

A diagram of a process flow

Description automatically generated

When delving into a prediction process, a sequence diagram painstakingly records the operations from the moment the system activates. The journey begins with the establishment of the main application and prediction application instances. Post instantiation, the system embarks on an initial UI setup, which includes presenting disclaimers, configuring window properties, and laying out the grid with its elements.

Following the UI setup, the system proceeds to display team logos, thus readying the interface for user engagement. This engagement is crucial as the selection of a team by the user sets off a series of events: the refreshing of team logos to mirror the current selection and the prevention of selecting duplicate teams, which could compromise the prediction's accuracy. With the interface set and user inputs in place, attention turns to ensuring the model is ready. This entails confirming the prediction model is loaded and primed for operation. Once the model's preparedness is established, the prediction process moves to its essential phase—determining the winner. At this juncture, the model analyses the input data to generate the prediction. The process culminates with the activation of the prediction button, leading the system to reveal the predicted outcome. This ultimate interaction epitomises the sequence of preceding operations, encapsulating the result of the complex message and data exchanges among the objects within the flow of the prediction application. Documenting these interactions in a sequence diagram not only chronicles the logical progression but also acts as a foundation for validating the design of the system and for guiding future improvements.

The test design plays a pivotal role in validating the functionality and reliability of the system. It ensures that all components work as intended individually and in integration, thereby guaranteeing the system's overall effectiveness and reliability. This involves systematically creating test cases for unit testing, integration testing, and system testing to cover all aspects of the system, from data import to predictive modelling and user interface functionality.

Unit Tests

* Data Import Functionality (F1): Test cases will verify the system's ability to import various formats of historical NFL game data accurately.
* Data Preprocessing (F2): Validate the cleaning, normalisation, and transformation processes of imported data to ensure compatibility with the machine learning model.
* Predictive Modelling (F3): Ensure the machine learning algorithm accurately interprets data and makes predictions based on historical patterns.
* Error Handling (F8): Test the system's ability to gracefully manage and report errors during data processing and prediction.
* Team Selection (F5): Verify that users can select NFL teams for predictions and the system correctly processes these selections.
* Data Visualisation (F9): Ensure the system can generate and display data visualizations accurately, enhancing the interpretability of prediction outcomes.
* Help and Documentation (F10): Test the accessibility and completeness of in-app guidance and documentation, ensuring it effectively supports user interaction with the system.

Integration Tests

* User Interface to Prediction Execution (F4, F6): Confirm that user inputs via the graphical user interface correctly trigger prediction execution and display results accurately.
* Model Training and Data Preprocessing Integration (F2, F7): Ensure that the model training process incorporates pre-processed data effectively, reflecting in the accuracy of predictions.

System Tests

* Full System Workflow: Test the entire application workflow from data import, preprocessing, team selection, prediction execution, to result presentation, verifying the integration and interaction of all components.

Each test case is designed to validate specific functionalities and their integration, ensuring comprehensive coverage of the system's capabilities. By rigorously testing each component, we aim to ensure the system's reliability, efficiency, and user-friendliness, adhering to the non-functional requirements such as performance (N.F.1), usability (N.F.2), and scalability (N.F.3). Focusing on predictive modelling (F3) and striving for a 60% or better accuracy rate directly supports the project's objective of advancing NFL game forecasting. Ensuring an intuitive user interface (F4) aligns with the aim of developing a user-friendly interface, facilitating easier interaction and engagement with the system.

Testing for efficient data handling and security (F8, N.F.6) ensures the system's credibility and trustworthiness, critical for user adoption and satisfaction. This test design framework is crafted to validate the functionality and reliability of your NFL prediction system comprehensively. By addressing both functional and non-functional requirements, the design ensures that the system not only meets its intended goals but also provides a reliable, user-friendly, and efficient tool for NFL game prediction analysis.

This chapter articulates the intricate design phase of the NFL predictor program, emphasising the transition from conceptual models to a fully operational system. The various design diagrams presented are paramount in visualizing and constructing a system that is robust, efficient, and user-centric.The diagrams— flowchart (or machine learning pipeline) & sequence —collectively facilitate a deep understanding of the system's architecture. They delineate user interactions, data flows, processing sequences, and the comprehensive journey from raw data to actionable predictions. The machine learning pipeline diagram, in particular, encapsulates the critical stages of data handling and model training, elucidating the system's logic and operation.These visual tools are not only blueprints for development but also act as crucial communicative instruments that encapsulate the system's envisioned functionalities and processes.

They serve to bridge the conceptual with the practical, ensuring that the application aligns with its core objectives: providing a user-friendly interface, implementing advanced predictive analytics, and offering an immersive user experience.

The detailed test design framework complements these diagrams by ensuring the system's components function correctly, both in isolation and when integrated. The comprehensive testing strategy, including unit, integration, and system tests, reinforces the system’s reliability, performance, and adherence to both functional and non-functional requirements. In essence, the designs contribute significantly to the effective functioning of the NFL predictor system, substantiating its capacity to meet the project's aims of predictive accuracy, intuitive user engagement, and adaptability to the evolving landscape of NFL game analysis. They are foundational to the system's development, guiding each step towards creating a reliable and proficient tool for NFL game prediction.

# Implementation

*Introduction*

The implementation of the NFL Predictor marks a pivotal phase in bridging theoretical design with practical application, embodying a comprehensive approach to sports analytics. This endeavour encapsulates not just the assembly of code, but the orchestration of a suite of technologies, methodologies, and design philosophies aimed at forecasting NFL match outcomes with unprecedented precision. At the heart of this project lies a meticulous integration of modular design principles, advanced machine learning algorithms, and user-centred interface development, each serving as a cornerstone to the tool's functionality and user experience. Commencing with a foundation built on the robust and dynamic capabilities of Python, the project leverages a rich ecosystem of libraries and frameworks to handle complex data manipulations, visualise intricate patterns, and execute sophisticated predictive models. The choice of Python and its ancillary technologies is a testament to the project's commitment to leveraging cutting-edge tools for data-driven insights. This strategic selection is further exemplified in the adoption of the RandomForestClassifier, a decision predicated on its adaptability and efficacy in navigating the multifaceted landscape of NFL game data.

As we delve into the specifics of the project's implementation, from the initial stages of data preprocessing and feature engineering to the nuanced development of the user interface, it becomes evident that each step is carefully crafted to not only meet but exceed the standards of modern software engineering. The subsequent sections will elucidate the development framework and design patterns that underscore the NFL Predictor, highlighting the integration of machine learning for analytical rigour, the employment of PyQt5 for a seamless user experience, and the comprehensive testing strategies that ensure the tool's reliability and effectiveness.

The development of the NFL Predictor was structured around modular design principles, facilitating separation of concerns, and enhancing code maintainability. By segregating the application into distinct modules for data loading, preprocessing, model training, prediction, and user interface management, the project adheres to the best practices in software architecture. This modular approach not only streamlined the development process but also simplified debugging and testing, ensuring that each component could be developed, tested, and refined independently.

The NFL Predictor is primarily developed in Python, a choice driven by Python's extensive ecosystem of data analysis and machine learning libraries. The tool integrates several key libraries including NumPy and pandas for data manipulation, seaborn and matplotlib for data visualisation, and scikit-learn for implementing machine learning algorithms. The choice of PyQt5 for the graphical user interface (GUI) reflects a commitment to creating a user-friendly application that is accessible to a wide audience, including those without a technical background.

The core functionality of the NFL Predictor hinges on the use of machine learning algorithms to analyse historical NFL data and predict match outcomes. Notably, the RandomForestClassifier from scikit-learn was selected as the primary predictive model due to its ability to handle the complexities and nuances of NFL game data effectively. Data preprocessing steps such as feature scaling with StandardScaler and dimensionality reduction with PCA and LDA were meticulously implemented to enhance model performance.

The implementation phase commenced with the loading and cleaning of datasets representing offensive, defensive, special teams, and game outcomes statistics from NFL matches. This process involved the removal of irrelevant features and the handling of missing data, ensuring the quality and integrity of the datasets used for model training. A critical part of the tool's functionality is its ability to predict the winner of a match between two teams. This is achieved through a predictive pipeline that includes data preprocessing, application of the trained RandomForestClassifier model, and post-prediction processing to interpret and display the results within the GUI. The PredictorApp class encapsulates the GUI components and logic, facilitating user interaction and the seamless execution of predictions.

The GUI design was carefully crafted to enhance user experience, featuring team logo displays, dropdown menus for team selection, and a clear presentation of the prediction results. The inclusion of a disclaimer dialog underscores the ethical considerations of the tool's usage, specifically its restriction to research purposes and prohibition against gambling.

The journey toward predictive accuracy begins with the meticulous preprocessing of historical NFL data, a foundational step critical to the success of the NFL Predictor. This phase leveraged data sourced from The Football Database, a resource renowned for its comprehensive and meticulously maintained datasets. The integrity and depth of the data available at www.footballdb.com were instrumental in providing a robust foundation for analysis. The website's commitment to data accuracy and its comprehensive collection of NFL statistics not only facilitated a detailed exploration of game dynamics but also ensured that our predictive models were grounded in reliable historical contexts.

The preprocessing pipeline was designed to address several key challenges inherent in handling real-world data. Initially, the focus was on cleaning the data to remove any inconsistencies or inaccuracies that could skew the analysis. This involved a rigorous process of identifying and correcting discrepancies, such as mislabelled data points or incomplete records. Following this, normalisation techniques were applied to standardise the scale of the data, ensuring that variables with larger magnitudes did not unduly influence the model's predictions. A significant aspect of the preprocessing stage was the strategic handling of missing values. Given the complexity and variability of NFL game data, missing entries were inevitable. The approach to managing these gaps in the dataset was twofold: employing automated methods to impute missing values where appropriate, and manually reviewing cases where automated imputation might introduce bias or inaccuracies.

The transition from preprocessing to feature engineering marked a shift toward leveraging domain knowledge to enhance the dataset further. This phase was characterised by the creative synthesis of new variables from existing data, aiming to unveil patterns or relationships not immediately apparent. One innovative strategy was the computation of ratios between offensive and defensive statistics. Such ratios offered a nuanced view of a team's performance, encapsulating the dynamic interplay between their offensive prowess and defensive strength. By quantifying this balance, the model could better assess a team's overall capabilities and predict game outcomes with greater accuracy.

The centrepiece of the NFL Predictor's analytical engine is the RandomForestClassifier, chosen for its robustness and versatility. This model stands out for its capacity to mitigate overfitting, a common pitfall in machine learning where models perform well on training data but poorly on unseen data. Additionally, its ensemble approach, aggregating predictions from multiple decision trees, renders it exceptionally adept at handling the complex, non-linear relationships that typify NFL game data.

Optimising the performance of the RandomForestClassifier involved a systematic search for the ideal set of hyperparameters, a task accomplished through a grid search technique. This process was meticulous, iterating over a predefined grid of hyperparameter values and evaluating the model's performance on a validation set at each step. The aim was to strike an optimal balance between model complexity and its ability to generalise across new, unseen data. This iterative training and evaluation cycle was pivotal in identifying the hyperparameter configuration that maximised predictive accuracy, ensuring that the NFL Predictor was equipped to make reliable forecasts. This expanded section elucidates the rigorous approach underpinning the NFL Predictor's development, from the initial stages of data preprocessing and feature engineering to the careful selection and tuning of its machine learning model. Each step was executed with precision, guided by both data-driven insights and deep domain knowledge, setting a solid foundation for the tool's predictive capabilities.

The design of the Predictor app GUI was informed by principles of human-computer interaction, aiming to provide a user-friendly and intuitive experience. Key elements of the interface include dynamic team logo displays, responsive dropdown menus for team selection, and a concise prediction result display. These features were carefully implemented using PyQt5, chosen for its comprehensive support for GUI development in Python. The GUI design also incorporates feedback mechanisms, such as displaying error messages for invalid inputs, enhancing the overall usability of the tool.

Comprehensive testing encompassed unit tests for individual components, integration tests to ensure seamless interaction between modules, and system tests to validate the end-to-end functionality of the tool. Test cases were designed to cover a wide range of scenarios, including edge cases and failure modes, to thoroughly evaluate the tool's robustness and reliability. The testing process not only confirmed the accuracy and efficiency of the NFL Predictor but also identified opportunities for optimisation, such as improving data loading times and enhancing model training efficiency.

Reflection on Testing Results and Future Directions

# Project Evaluation

# Further Work and Conclusions

# Glossary

Artificial Intelligence (AI): The simulation of human intelligence processes by machines, especially computer systems. These processes include learning, reasoning, and self-correction.

Artificial Neural Networks (ANNs): Computing systems vaguely inspired by the biological neural networks that constitute animal brains. ANNs learn to perform tasks by considering examples, generally without being programmed with task-specific rules.

Data Preprocessing: The process of cleaning and organizing raw data before it is analysed. This includes handling missing values, normalizing data, and encoding categorical variables to ensure the data is in a usable format for analysis.

Dimensionality Reduction: The process of reducing the number of random variables under consideration by obtaining a set of principal variables. Techniques such as PCA (Principal Component Analysis) and LDA (Linear Discriminant Analysis) are used for this purpose.

Ensemble Methods: Techniques that create multiple models and then combine them to produce improved results. RandomForestClassifier is an example of an ensemble method.

Feature Engineering: The process of using domain knowledge to extract features (characteristics, properties, attributes) from raw data. These features can be used to improve the performance of machine learning algorithms.

Machine Learning: A subset of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.

PCA (Principal Component Analysis): A statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components.

PyQt5: A set of Python bindings for The Qt Company’s Qt application framework, used for developing graphical user interfaces (GUIs) and multi-platform applications.

RandomForestClassifier: A machine learning algorithm for classification tasks, which operates by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes of the individual trees.

Scikit-learn: An open-source machine learning library for Python that offers simple and efficient tools for data mining and data analysis.

StandardScaler: A technique in preprocessing that standardizes features by removing the mean and scaling to unit variance.

# Table of Abbreviations

|  |  |
| --- | --- |
| **Abbreviation** | **Definition** |
| AI | Artificial Intelligence |
| ANNs | Artificial Neural Networks |
| API | Application Programming Interface |
| BP | Back-Propagation |
| CART | Classification and Regression Trees |
| F.R | Functional Requirement |
| GUI | Graphical User Interface |
| LDA | Linear Discriminant Analysis |
| LMT | Logistic Model Trees |
| ML | Machine Learning |
| N.F | Non-Functional Requirement |
| NFL | National Football League |
| PCA | Principal Component Analysis |
| PyQT | Python binding of the cross-platform GUI toolkit Qt |
| SVM | Support Vector Machine |

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# Appendix A: First Appendix