Machine Learning Based Coaching Tool for American Football Offensive Play Design: Literature Review

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Introduction. This literature review compiles 12 full papers providing motivation and support for our proposed CPSC502.1A research project for Fall 2022-Winter 2023. The related topics covered in these papers include Big Data Bowl submissions [1,2], Long Short Term Memory (LSTM) neural networks for trajectory prediction [3,4,5,6,7], visualization and analysis of sports data [8,9,10,11] and Radio Frequency Identification (RFID) tracking technology [12].

[1] Kyle Burris. 2019. A trajectory planning algorithm for quantifying space ownership in professional football. (Jan. 2019). https://operations.nfl.com/media/3665/big-data-bowl-burris.pdf

Summary. In this report, Kyle Burris analyzes the space ownership of offensive and defensive teams in NFL football games using data from an NFL tracking dataset provided in the 2019 Big Data Bowl competition. This analysis provides a method of player and team performance evaluation to NFL football teams and coaches and is a finalist submission in the 2019 Big Data Bowl competition. The proposed solution in this report is a model that computes space ownership using an optimization algorithm that considers player-specific features such as acceleration to determine which player can arrive at the given space in the shortest time. This model was then utilized by a neural network to predict the time of arrival of each player at a given time during a play, to each square yard partition of the field. The model's calculation was updated every tenth of a second for an accurate representation of field control given a specific play in a game. In a specific example, a 64-yard touchdown pass depicted field control and an individual error causing offensive field control gain, from the moment of snapping the ball to 3.5 seconds after the snap. The authors of this report provide a novel physical model to calculate space ownership of each team in an American football game, at any given time. This report also exhibits an application of the physical model which is evidence of the possible value provided to NFL teams, coaches and sports analysts utilizing this tool.

Rationale. Our proposed solution will also be making use of the Big Data Bowl dataset and player tracking to solve a different problem. The utilization of a neural network and player positioning data for computation of space ownership provides motivation for our solution which will predict the trajectory of the defensive team.

Strengths.
- The authors of this report offer a novel solution to a well defined problem that, in contrast to previous works, considers player-specific characteristics.
- This report provides the neural network approximation as an example of a useful application of the physical model, portraying the model's accuracy and applicability.

Weaknesses.
- This report does not offer many comparisons with other "space ownership" models or related work. Evidence of the accuracy of alternative methods in comparison to the proposed method would provide further support of applicability.
- This report lacks further support of the model's accuracy by demonstrating its findings in a single example that does not portray the extensive evaluation process for the model.

Questions For The Author. How can space ownership be quantified when two players of opposing teams occupy the same space? Could player-specific attributes be used to identify the success of a receiver that is occupying the same space as a defender?

What We Can Learn. Much like the authors of this report did, we will be identifying input parameter restrictions so that our model will solve a specific and simplified problem. We will also provide a clear evaluation process to assess our model in comparison with other modern methods.

[2] Graham Pash and Walker Powell. 2019. A mixed-data predictive model for the success of rush attempts in the national football league, (Dec. 2019). https://operations.nfl.com/media/4207/bdb_pash_powell.pdf

Summary. In this report, Graham Pash and Walker Powell create a cumulative distribution model to predict the probability of yard gain from a running play. This report is a finalist submission in the 2020 Big Data Bowl competition and provides a model for NFL coaches, teams and sports analysts interested in running play design, success prediction and player performance evaluation. The authors use the concept of Player Influence Areas to quantify the control of each individual player on the field, which is then accumulated for a quantitative value of field control. The authors construct a model to determine the probability distribution of yard gain predictions in a given play. The authors then trained a multilayer perceptron, a convolutional neural network (CNN) and a mixed-data model utilizing processed Big Data Bowl data and the aforementioned probability model. The authors compared the Continuous Ranked Probability Score (CRPS) loss function outcome of all three models using test and validation subsets of the Big Data Bowl dataset to determine the best performing models. The predictive model was then used to predict the average yards of plays run by rushers in comparison with the computed average of the CNN model yard gain prediction. The authors concluded that the CNN delivered the most optimal CRPS value and provided an accurate predictive model to aid in successful run play prediction . This report demonstrates the importance of field control analysis using spatial data in predicting yard gain probability.

Rationale. We will also be preprocessing spatiotemporal data and training a predictive neural network to solve our trajectory prediction problem. This report provides evidence of the utilization of this data, which we can consider when implementing our own tool.
Strengths.
- The authors provide a clear comparison of the proposed method when implemented by three different models.
- The authors provide an example of the usage of the most successful predictive model (CNN) to evaluate rusher performance by expected versus actual yard gain from run plays.

Weaknesses.
- The authors provide performance analysis for individual players but fail to consider classifying routes and the routes that were run by each of these players, which could serve as a useful and more accurate assessment.
- This report provides a comparison of the performance of the three predictive models, but does not offer a comparison of the constructed probability model with any other existing models, which is valuable in assessing the probability model's accuracy.

Questions For The Author. How would a different neural network perform in comparison with the CNN? Can we determine the most important factors of overperforming rushers and their runs using this model?
What We Can Learn. We will apply similar methods provided in the report related to spatial data processing and model training. The idea of field control is also an important factor for player movement prediction, and is an attribute to consider in our project.

[3] John Violos et al. 2020. Next position prediction using lstm neural networks. In *11th Hellenic Conference on Artificial Intelligence* (SETN 2020). Association for Computing Machinery, Athens, Greece, 232–240. ISBN: 9781450388788. DOI: 10.1145/3411408.3411426

Summary. In this report, Violos et al. explore the use of Deep Learning (DL) techniques for predicting the next position of moving objects, serving as a useful application for Machine Learning users and researchers. The authors focus on the use of Artificial Neural Networks (ANN) by using LSTM layers for next position prediction alongside a genetic algorithm and transfer learning method to train the model. The authors design and build a model utilizing LSTM layers and evaluate the performance of LSTM ANN for spatiotemporal data by testing the model with data from vessels and trajectories. The authors also experimented the use of a genetic algorithm to provide a smart search for an estimated optimal ANN architecture. Finally, the authors provide an analysis of improving the training process of ANN models by utilizing two types of transfer learning methods; Transfer Train and Model Retrain. The authors provided a comparison between the proposed model, which utilized LSTM layers and a genetic algorithm, and three state-of-the-art models including 2 machine learning meta models and a Gradient boosted decision tree model. The authors evaluate performance of each model using the Vincenty formula and the training time of each model. The Vincenty formula computes the distance between two points and provides an accurate representation of error for the predicted positions produced by each model. The authors concluded that DL Networks trained with the genetic algorithm outperformed the alternative state-of-the-art models by a significant amount. The authors also indicate that each of these transfer learning methods drastically improve the model training time with little sacrifice to accuracy.
Rationale. Since we will be implementing an LSTM model in the same Machine Learning framework for player positioning prediction, the information in this report supplements our motivation for utilizing LSTM. This report provides a useful analysis of the accuracy of LSTM models in comparison with alternative state-of-the-art models for trajectory/position prediction.
Strengths.
- The authors support the accuracy of their model compared with state-of-the-art models by computing a meaningful measurement of error using the Vincenty formula.
- The authors support the practicality of their model by providing a documented implementation.

Weaknesses.
- The authors provide a single visual example of the model used for position prediction in comparison to the true position values. Further accuracy comparisons would provide support to the practicality and accuracy of the model.
- The authors provide a limited section on transfer learning methods to improve model training time. Rigorously demonstrating the improvement of training time of a model versus the effects on accuracy when utilizing transfer learning would add value to the reports findings.

Questions For The Author. Aside from training time of the proposed model, what is an identified or possible drawback of using this model in comparison with its alternatives? How would an alternative neural network affect the results of the proposed model?
What We Can Learn. This report suggests LSTM neural networks can be utilized for accurate prediction of spatiotemporal problems which provides motivation for our proposed solution to a trajectory prediction problem.

[4] Florent Altché and Arnaud de La Fortelle. 2017. An lstm network for highway trajectory prediction. In *2017 IEEE 20th International Conference on Intelligent Transportation Systems (ITSC)*, 353–359. DOI: 10.1109/ITSC.2017.8317913

Summary. In this report, Florent Altche and Arnaud de La Fortelle approach the problem of predicting highway trajectories of vehicles by utilizing an LSTM neural network. Finding an accurate model to predict trajectories can have powerful implementations, such as improvement of existing self-driving car systems that currently lack effective predictive functionality. The authors propose a model for trajectory prediction of a target highway vehicle that utilizes a single LSTM layer and they train a regression function to compute predicted outputs with the least error. The authors train the aforementioned model, and several variation models, with 80% of a US highway dataset (US101), considering only nearby vehicles in the trajectory prediction of the target car. The results were then analyzed by comparing the prediction error of each of the trained models using Root Mean Squared error (RMS error). The authors computed errors in the prediction of lateral positions, longitudinal speed and with information on the prediction horizon (long term prediction). The authors of this report conclude that the proposed solution yielded an average RMS error lower than previous state-of-the-art models, particularly for lateral positions. Moreover, the authors identified a drawback to their model, providing evidence of prediction delay for longer predictions in the future. The authors also concluded that longitudinal velocity prediction benefits from predictors such as car model, likely due to relevant car characteristics such as acceleration ability.

Rationale. This report demonstrates the applicability of LSTM neural networks in trajectory/path prediction problems. Where this model predicts highway vehicle trajectory, we will be predicting defensive team player trajectory in football.

Strengths.

- This report provides a useful comparison between alternative models and the proposed model, and an accurate assessment of the prediction horizon which is relevant to the problem.
- This report provides an accurate model with real life applications capable of producing highly accurate predictions.

Weaknesses.

- The model experiences a delay with the expected result for long term predictions. This is harmful to the applicability of the model for products and requires further analysis.
- It is difficult to determine whether or not this model would succeed in a practical implementation, for example, a car driving system. Building on this work for a prototype or other application would be very useful for supporting the applicability of the findings of this research.

Questions For The Author. Is it computationally feasible to apply this type of model into a usable system and mass produce it? How significant is the delay of long-term prediction if the model is applied in a prototype?

What We Can Learn. We will apply a similar problem definition. The proposed model takes a target vehicle to compute its trajectory in response to the trajectory of other vehicles, which in our case would be a target player in response to surrounding players.

[5] Alexandre Alahi et al. 2016. Social lstm: human trajectory prediction in crowded spaces. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR).* (June 2016), 961–971

Summary. In this report, Alexandre Alahi et al. explore the problem of predicting pedestrian trajectories while taking into consideration social conventions, accommodation of other pedestrians and other nearby obstacles. Being able to predict pedestrian trajectories can have implementations such as autonomous vehicles and suggests the ability of LSTM models for predicting trajectories. The authors propose a "Social" LSTM model to predict human trajectory and behavior in response to obstacles and other pedestrians. This considers a crowd of people as a scene, and attempts to compute an LSTM network for each trajectory in a scene. These results are then accumulated through "Social Pooling" which allows individual LSTM networks to share information with one another about their predicted trajectories. Through social pooling, an LSTM cell receives pooled information from neighboring LSTM cells, which in response affects the state of the initial LSTM cell. The authors trained and tested the Social LSTM model using two public human trajectory datasets, each with two scenes that represent real world crowded settings with non-linear trajectories. The prediction error of the Social LSTM is calculated using three different metrics; Mean Square Error (MSE), Final Displacement Error, and Average Non-Linear Displacement Error. The Social LSTM was also evaluated in comparison with state-of-the-art trajectory predictive models and multiple control settings. The authors compare the performance of the models by analyzing the three aforementioned error metrics. The authors concluded that the proposed model outperformed alternative models when predicting on standard datasets. The authors also provide non-linear examples of the Social LSTM predicting trajectories, suggesting the effectiveness of the Social LSTM for problems that require consideration of other pedestrians and obstacles.

Rationale. Where this model considers social norms and mannerisms for trajectory prediction, our model will consider the effects that an offensive player will have on the expected trajectory of a defender. The proposed model in this report also provides an interesting concept with the "Social Pooling" of different LSTM cells, which is something we will keep in mind for our own project.

Strengths.

- This report provides a useful comparison of the Social LSTM in comparison with alternative models and control settings. These comparisons support the effectiveness of the Social LSTM for non-linear trajectory prediction.
- This report provides qualitative examples and provides images displaying the comparison of predicted trajectories with the true trajectory, supporting the applicability of the model.

Weaknesses.

- The practicality of the proposed model is harmed due to the requirement of analyzing individual scenes and LSTM cells for each trajectory. A discussion on the feasibility of this model would be beneficial for further research and implementation.
- The proposed model is limited to pedestrian trajectories and does not consider additional objects or beings with trajectories. The effectiveness of this LSTM could be analyzed further by generalizing it to other objects or entities, which is perhaps future research for the authors or others interested in this topic.

Questions For The Author. How could this Social LSTM be applied to a device such as an "autonomous vehicle"? What additional measures would have to be taken to generalize this Social LSTM for objects/beings with additional trajectories?

What We Can Learn. We will consider the conventions of a football game to define our problem and solution. We will also consider the grouping the results of expected trajectories for more accurate trajectory predictions in our project.

[6] Yu Zhao et al. 2018. Applying deep bidirectional lstm and mixture density network for basketball trajectory prediction. *Optik*, 158, 266–272. DOI: https://doi.org/10.1016/j.ijleo.2017.12.038

Summary. In this report, Yu Zhao et al. explore solutions to the problem of manual sports data collection and analysis for basketball strategy development using BLSTM and MDN networks. A tool capable of predicting basketball trajectories and analyzing data is valuable for coaches and players to determine zones of success and predictors for successful shots. The authors propose a Bidirectional LSTM and Mixture Density Network approach that is capable of predicting basketball trajectories on real data and producing new trajectory samples. The BLSTM-MDN model approach benefits from the spatiotemporal learning ability of deep BLSTMs as well as the usage of the full probability distribution generated by MDN. The authors train the proposed model and alternative models using real sports data from the 2015-2016 NBA season. The performance of each model was then evaluated using the Area Under Curve value of each model for shots at different distances from the basket. The proposed model was also used to generate trajectory predictions using real data, which proved to be very close to the true trajectory values in the experiment. The proposed BLSTM-MDN model outperformed every deep learning and non-deep learning model for predictions over 2 feet of distance from the basket. The generated trajectories of the model also proved accurate, demonstrating the ability of the model to predict ball trajectory.

Rationale. Where this report provides a novel method for trajectory prediction in basketball using real game data, our project will be applying similar methods, including LSTM, for trajectory prediction of defenders in a football game. We will also compare our model with state-of-the-art alternatives.

Strengths.

- The authors support the accuracy of the proposed model by comparing results of other approaches, including deep learning and non-deep learning models.
- The authors combine the well known attributes of both BLSTM and MDN models to create a combined model that benefits from the advantages of both of these models for the given problem.

Weaknesses.

- The authors do not provide any use cases or examples of the proposed tool for practical game data analysis which would provide further evidence of the applicability of the proposed tool.
- The proposed tool in the report is limited to trajectory prediction for basketball games. Further research on the model would support the generalization for other trajectory problems.

Questions For The Author. Can player-specific features be taken into consideration for the prediction of shot success probability?

What We Can Learn. BLSTMs have a high capacity for learning when applied to spatiotemporal problems, which is motivation for our own project. We will also apply similar methods of training our model and the comparison of it with alternative approaches.

[7] Chujie Wang et al. 2019. Exploring trajectory prediction through machine learning methods. *IEEE Access*, 7, 101441–101452. DOI: 10.1109/ACCESS.2019.2929430

Summary. In this paper, Chujie Wang et al. investigate human trajectory prediction through the application of different machine learning methods by conducting an analysis into methods for mobility prediction composed of continuous coordinates, with the goal of constructing an applicable model. The authors propose a basic LSTM framework for single user trajectory prediction and a Seq2Seq framework utilizing LSTM for multi-user multi-step prediction. The frameworks were trained and tested on a model-based mobility dataset and a realistic dataset. The authors compared basic LSTM framework predictions with the results of linear regression, as well as the true position values of the tested trajectories. The authors compared LSTM-based Seq2Seq framework with alternative methods of trajectory prediction including linear regression, LSTM, Support Vector Regression, and more. From the results, the authors concluded the basic LSTM framework outperformed linear regression for single user trajectory predictions. The multi-user based experiments also suggested the best performing method yielding the lowest mean squared error (MSE) was the proposed LSTM-based Seq2Seq framework.

Rationale. This research supports the decision to use LSTM in our project and provides meaningful evidence of the effectiveness of LSTM-based frameworks for multi-user path prediction.

Strengths.

- The authors provide a framework for single and multi-user path prediction with an accuracy comparison against alternatives.
- The authors demonstrate an effective generalized framework and suggest its applicability in practical uses such as mobility management, sports analytics and more.

Weaknesses.

- The authors do not provide an example of an application of their framework. Demonstrating a use case of their framework would support the effectiveness and applicability of their model.
- The current multi-user framework has the disadvantage of longer training, which can be harmful to the applicability of the model.

Questions For The Author. What occurs when two entities are predicted to collide? Can this model be enhanced to handle collisions or trajectories of crowded spaces?

What We Can Learn. We have motivation that LSTM is a powerful framework to utilize for trajectory prediction. We will also consider that an LSTM-based Seq2Seq framework is more effective than a basic LSTM framework.

[8] Toshihiro Tani et al. 2015. Sports play visualization system for american football. In *Proceedings of the international multiconference of engineers and computer scientists*. Vol. 1

Summary. In this paper, Toshihiro Tani et al. explore visualization tools to aid in game analysis, strategy design and decision making in sports. The ability to visualize games and player movement aids coaches and sports analysts to construct informed strategies and evaluate performances. The authors propose a visualization system for American Football named "SportsViz". This interactive system is capable of taking user input, reading from a provided database, clustering plays, visualizing plays and video output. The search, play classification, and visualization functions make up the system, which are responsible for extracting play data, classifying plays using trajectories and creating a visualization, respectively. The system will then produce a visual tab for each cluster or play classification with a video feature. The authors test their proposed tool by providing a few examples of their visual tool used for play analysis. The authors display the play trajectory example alongside the output classification by the SportViz tool, suggesting the effectiveness and accuracy of the classification and visualization. The authors conclude their system offers play classification of game data and provides visuals and video features to users. The proposed solution is an initial approach to aid in sports strategy design using visualization and suggests future possible applications.

Rationale. We will be providing a similar visualization tool that utilizes an LSTM neural network for a predictive model. For our project, we can consider user inputs, visualization techniques and additional "nice-to-have" features introduced in this paper.

Strengths.

- The proposed solution in this report is very practical and the authors articulate this by providing several examples of using the tool for play classification and visualization.
- The features of the solution are well defined by the authors and clearly demonstrated in the implementation of the tool. Usage of the tool becomes immediately obvious from reading the report.

Weaknesses.

- This tool is very limited and operates to fulfill a specific job. The user interface and existing features of the tool can be expanded and improved, supporting practicality for play design.
- The evaluation of this tool is done through displaying the classification of play data and the visual results. Analyzing the user interface, efficiency and general user interaction and sentiment would support the applicability of this tool.

Questions For The Author. How is the data for this tool preprocessed? How can this tool be generalized to other ball sports?

What We Can Learn. We will take inspiration from concepts used to build this tool, but improve using modern technology to produce a user-friendly interface for visualization of our predictive model.

[9] Manuel Stein et al. 2016. From game events to team tactics: visual analysis of dangerous situations in multi-match data. In *2016 1st International Conference on Technology and Innovation in Sports, Health and Wellbeing (TISHW)*, 1–9. DOI: 10.1109/TISHW.2016.7847777

Summary. In this paper, Manuel Stein et al. investigate the usage of spatiotemporal data in soccer matches for analysis and information visualization. With the growing accuracy and accessibility of this data, sports analysts, professional teams and their coaches benefit from an effective approach of analyzing this data for strategy design. The authors provide a system to analyze a soccer team's players' trajectory data, focusing on set pieces (corner kicks, free kicks, etc…) as an initial step towards using this system for sports strategy analysis. The proposed system considers the following: analyzing starting positions and trajectories of players, clustering different types of set piece events, and providing further details such as a legal defensive wall obstruction. The authors evaluated their approach through several case studies that assessed how their system performed when analyzing real game data to provide positional information. The results of their data provided evidence that the system can classify player roles in free kicks, derive differences in set pieces, and provide a comparison of the two teams to determine superior set piece organization, and strength. The authors conclude this system can interpret a soccer game's set pieces, using information visualization and analysis of player spatial data. This tool provides value to sports analysts and is an initial contribution to analyzing and visualizing an entire game.

Rationale. This report provides sports data visualization and analysis methods for providing insights useful for strategy design. Where this paper analyzes and visualizes soccer game set pieces, we will be analyzing football plays applying similar concepts.

Strengths.

- The case studies in this report provide clear evidence of the applicability of the proposed system, and the value it has for game analysis and strategy planning.
- The authors of this report provide a purposeful breakdown of the analytical and visualization methods used for formation analysis, tactical analysis and additional details of set plays.

Weaknesses.

- The authors of this report do not provide a comparison of existing systems with the proposed system. A comparison highlighting the advantages and disadvantages of existing state-of-the-art systems would provide useful information to the reader.
- The limitations of this system are evident with the system intended for set piece plays, which are a small subset of a soccer game. Generalization of this for other sports or for different aspects of the game would improve the applicability of this system.

Questions For The Author. How can this tool be generalized to other components of a soccer match? How much does the complexity of the problem increase when analyzing an entire game?

What We Can Learn. We will apply similar visualization concepts in our own project, and compare our model with alternative existing solutions to provide evidence of the effectiveness of our project.

[10] Halld'or Janetzko et al. 2014. Feature-driven visual analytics of soccer data. In *2014 IEEE Conference on Visual Analytics Science and Technology (VAST)*, 13–22. DOI: 10.1109/VAST.2014.7042477

Summary. In this paper, Halld'or Janetzko et al. explore the usage of spatiotemporal soccer data with visual analytics methods to provide player and match performance analysis, valuable to scouts, coaches and teams. The proposed system in this report considers three different views of analysis for an entire game: single player analysis, multi-player analysis and event-based analysis. This approach offers flexibility, being able to identify specific player features, team formations, player movement patterns, and separate analysis of events of interest, such as crosses. This provides coaches with several different visual analytical measures for the performance of a game and utilizes modern data mining techniques to do so. The authors provide use cases of their proposed system as evidence of the applicability of their tool. The authors use their tool to conduct analysis of a forward player, investigate shot event classification and the formation of the defensive line. The authors measure success by the analysis capabilities the tool provided, and through positive feedback received from a soccer expert. The authors conclude the novel tool is useful to sports analysts and coaches for single player, multi-player and "special" event evaluation.

Rationale. We will provide a similar visual analysis system for football coaches, but instead of identifying and classifying features, we will be predicting outcomes of defensive player trajectories. Here we can derive many concepts and methods for visualization and analysis to consider for our own project.

Strengths.

- The authors provide a tool that is not limited to a particular feature of the game. This tool has the flexibility to provide visual analysis of special events, plays and team formations.
- The authors provide a case study demonstrating the usage of the tool for analyzing three game features, which is evidence of the tool's effectiveness for the aforementioned types of analysis.

Weaknesses.
- The evaluation of the tool does not include comparison with alternative visual analysis models. A comparison between this tool and existing systems would support the tool's applicability.
- The visualization produced by the system is limited from a user perspective. The creators could improve the user interface and implement or test other visualization methods.

Questions For The Author. How could this tool be expanded to fit other ball sports, if possible? How would this affect the current problem definition that analyzes three game features?
What We Can Learn. We will derive visual analysis techniques in this report for our own solution and apply a comparison of our model with alternative methods for an accurate evaluation.

[11] Alina Bialkowski et al. 2014. Large-scale analysis of soccer matches using spatiotemporal tracking data. In *2014 IEEE International Conference on Data Mining*, 725–730. DOI: 10.1109/ICDM.2014.133

Summary. In this paper, Alina Bialkowski et al. explore the usage of player and ball tracking data from a professional soccer league to capture player roles for individual and team formation analysis, valuable to coaches and sports analysts that are in search of insights from available datasets. The authors provide a "Minimum Entropy Data Partitioning" method of role-based representation of the players on the field utilizing the tracking data. The authors determine the optimal formation representation by minimizing the entropy of the set of player role distributions resulting from the expectation maximization (EM) algorithm. The authors test the method using a soccer player tracking dataset including data from 380 professional games. The authors determined the role probability distribution of each individual player in this dataset and used these results to group formations into clusters that separate formations by features. The resulting clusters are then compared with a soccer expert's labels of formations for each of these teams. The proposed method's results agreed with the expert in 75.33% of the classifications, which supports the accuracy of this method. Overall, the authors contribute an accurate method for classifying player tracking data into individual player roles, and consequently, team formations.
Rationale. Where this tool provides classifications of player roles, we will be applying the tracking data to predict future trajectories. This report provides motivation for the usage of player tracking data to analyze trajectory trends.
Strengths.
- The proposed method offers accurate player role classification over different periods of the game, considering events where players switch positions mid-game.
- Evidence comparing the classifications with an expert's opinion supports the applicability of this tool for practical usage and a step towards automating player role classification.

Weaknesses.
- The proposed solution is not compared with other state-of-the-art models. Evidence of this method in comparison with alternative approaches would further support the applicability of the method.
- The existing solution is limited as it does not have a convenient method of displaying its results. The applicability of this method would be better represented in a prototype displaying the classification of roles and formations in real time using real data.

Questions For The Author. Can this method generalize offensive versus defensive formations of teams throughout a game?
What We Can Learn. We will apply similar methods of data processing and problem definition for our project. We will also provide a visualization tool to suggest the applicability and practicality of our prediction methods.

[12] Ricardo Tesoriero et al. 2009. Tracking autonomous entities using rfid technology. *IEEE Transactions on Consumer Electronics*, 55, 2, 650–655. DOI: 10.1109/TCE.2009.5174435

Summary. In this report, Ricardo Tesoriero et al. explore available technologies for accurate and precise collection of tracking data capable of several practical applications for tracking in sports, farming, robotics, and more. The authors propose a system based on passive RFID technologies that is capable of tracking autonomous robots in an indoor environment. The system maps physical surfaces to a grid of "location units" using RFID tags. RFID readers attached to the tracked entities retrieve and send location unit information to the Location Manager (LM) which determines the "full location path" of the tracked entity and maps this information on a Tracking Presentation Screen. The authors test their system for the robot tracking problem by attaching RFID readers to the autonomous robots for tracking. The authors evaluate the effectiveness of the system by using the time it takes the reader to recognize a tag (reader timeout) and the time spent on reading (reading time). The discovered results suggest the accuracy of the system, particularly for longer reader timeout and reading times. In conclusion, the authors provide a system for tracking autonomous entities in an indoor space with accurate results outperforming most other existing alternatives, with the benefit of low cost and maintenance.
Rationale. This report provides evidence supporting the tracking accuracy of data sets collected through RFID technology, which we will be using in our own project.
Strengths.
- The authors exemplify a practical usage of the proposed system for solving the robot tracking problem, which demonstrates the applicability, accuracy and precision of RFID technology.
- The authors provide an evaluation of the effects of reader timeout and reading time on the detection of RFID tags in location units, affecting the accuracy and precision of the system's results.

Weaknesses.
- The authors claim the superiority of their system without assessing the performance of alternatives. This claim can be supported by comparing alternative results in the robot tracking problem.
- The proposed system is limited to 2D systems and relies on surfaces that contain RFID tags. Having the ability to locate an entity in 3D space would provide further applicability of the tool.

Questions For The Author. How can RFID technology be applied to detect further details of a moving entity, for example in 3D spaces or movement of different parts of the entity?
What We Can Learn. This report suggests the accuracy of trajectory data collected through RFID tags, which is encouraging for our project which will rely on the NFL data set, collected using RFID.