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Can artificial intelligence revolutionize soccer tactical analysis?

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Abstract

Introduction. Adopting appropriate tactics and strategies is crucial for soccer teams aiming for victory. Soccer is undergoing a transformative renaissance with an infusion of artificial intelligence (AI), propelling a domain of tactical analysis into uncharted territories. Aim of Study. This narrative review seeks to provide a thorough overview of methodologies, challenges, and potential of AI in soccer tactical analysis. By collating current research, it aims to underscore AI's transformative impact on soccer analysis, contributing fresh perspectives on tactical aspects. Material and Methods. A search was conducted in the Scopus, Web of Science, and EBSCO databases on August 29th, 2023, using a BOOLEAN expression to identify research articles in English on AI applications in soccer tactics. Results. From an initial pool of 90 articles, 23 were selected for review after screening for relevance and application of AI techniques in soccer tactics. These studies showcase AI's diverse applications, from predictive analytics and real-time adjustments to pattern recognition and strategic planning. Conclusions. The integration of AI into soccer tactical analysis marks the beginning of a new era characterized by data-driven strategies and performance optimization. Through advanced machine learning (ML) models, neural networks, and complex algorithms, AI facilitates deeper, actionable insights into game dynamics and opponent strategies. This review enriches a scientific discourse by detailing AI's pivotal role in modern soccer tactics, suggesting a future in which AI's potential is fully harnessed, signifying a milestone in soccer's analytical evolution.

KEYWORDS: neural networks, performance analysis, sports technology, machine learning, decision-making, soccer tactics.

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Introduction

Theoretical background

Soccer is an intricate sport with numerous unpredictable situations [41]. Match analysis pertains to objective recording and study of behavioral occurrences during matches [7]. As a result, performance analysis is deemed an indispensable tool for team coaching staff, while also representing an extensive field of research [43]. Over time, incorporation of advanced technologies and extensive data has revolutionized soccer coaching, providing deeper understanding of game's nuances [42]. One of the most promising advancements in this context is an application of artificial intelligence (AI) techniques, which unveil new horizons in performance analysis [44]. AI can efficiently scrutinize team behavior in a way that is easily comprehensible for people and suitable for data analysis [37]. This literature review explores a burgeoning field of AI-powered soccer tactical analysis, delving into a spectrum of methodologies, challenges, and implications that this intersection brings to the forefront.

Soccer, as a complex team sport, presents a dynamic web of interactions. Tactical decisions on formations, player positioning, movement patterns, and strategic plays are vital components that determine a team's success [19]. Traditionally, an analysis of these aspects relied on manual observation, expert insights, and statistical assessments [38]. However, limitations of these traditional methods became evident as soccer evolved into a more data-driven and technologically advanced arena. Modern tracking systems, wearable sensors, and video recording tools have generated an unprecedented volume of data, transforming soccer into a data-driven sport [33].

By using AI, a field of computer science that focuses on creating systems, scientists can simulate human-like intelligence and decision-making [9]. At the heart of the AI revolution lies an ability to harness the power of machine learning (ML) algorithms, neural networks, and other AI methods to make sense of vast and complex datasets [27]. For instance, ML algorithms can sift through large amounts of match data to recognize patterns in player's behaviors, team formations, and strategic choices [22]. Deep learning techniques, inspired by human brain's neural networks, allow computers to recognize and interpret visual cues from video footage [1], enabling extraction of valuable tactical insights from match recordings.

Implications of AI-powered soccer tactical analysis extend beyond sidelines. Coaches, players, and analysts can now delve deeper into performance evaluation. AI-driven insights also provide a comprehensive view of opponents' strategies, strengths, and vulnerabilities, offering teams a competitive advantage by enabling more effective pre-match preparations [17]. Furthermore, coaches can gain more comprehensive understanding of their team's strengths and weaknesses [3], enabling data-driven strategy formulation. By identifying individual players' strengths, weaknesses, and preferences, AI can aid in designing personalized training regimes and tailored strategies [5]. Moreover, AI tools can support real-time decision-making during matches, providing insights that coaches can act upon immediately [24]. As a result, AI contributes to a paradigm shift in soccer coaching, promoting data-driven decision-making that complements intuition and experience of coaches.

While the potential of AI in soccer tactical analysis is undeniable, challenges remain. Data privacy, ethical considerations, and potential for overreliance on technology are among the concerns that need to be carefully addressed [25]. Moreover, the integration of AI methods requires collaboration among sports scientists, data analysts, and soccer experts to ensure a holistic approach that leverages both AI capabilities and domain expertise [38]. The focus must be on developing interpretable AI models which provide insights that are understandable to coaches and players [6]. As AI algorithms continue to advance, potential for more sophisticated predictive models, real-time analysis, and automated decision support systems is within reach.

What can tactical analysis in soccer involve?

In soccer, a team's tactical behavior plays a crucial role in determining their performance. A tactical behavior pertains to how teams manage space and time through player actions [46]. According to Teoldo et al. [52], anything related to decision-making on a field falls under a category of tactical elements. Therefore, as per the authors, aspects such as tactics, strategy, phases and moments of play, systems and schemes of play, and tactical principles should all be included and studied. Essentially, these elements refer to coach's ideas, which define a team's Game Model (Figure 1) [41]. Thus, from now on, any reference to tactical analysis in soccer will include everything that can be related to coach's philosophy (strategies, tactics, principles, formations, playing styles, and key moments of a game), but also individual tactical abilities of players. All these aspects need to be assessed in relation to factors relevant to an opposing team and an overall context of a match [46].

Tactical principles serve as a foundation for team's execution of particular motor actions and patterns. They can be divided into three levels of complexity: main, sub-, and sub-sub-principles. Main principles encompass collective actions, sub-principles deal with sectorial and inter-sectorial actions, while sub-sub-principles focus on individual actions. These components are interrelated, forming a cohesive structure that reflects team's distinctive identity [10]. Team's formation, which dictates players positioning on a field, is commonly referred to as a playing system. This formation is typically represented by a series of numbers indicating a number of defenders, midfielders, and forwards [47]. While the formation represents a static spatial arrangement, it profoundly influences and facilitates desired behaviors of a team [10]. Playing styles encompass recurring patterns and behaviors adopted by teams during matches [23]. Lastly, the term "tactics" refers to specific actions executed by soccer players within a broader context of a team's overall strategy [7].

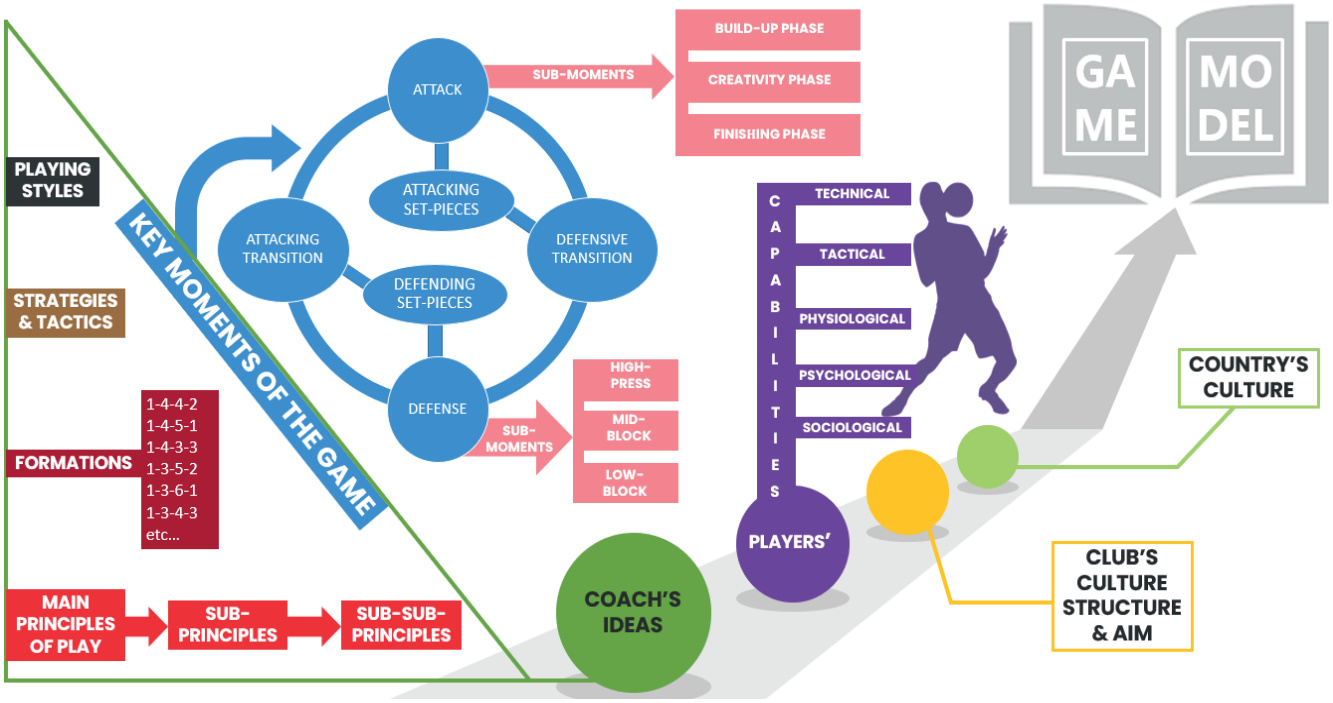

Figure 1. Factors that contribute to creation of a Game Model. Source: Plakias [41]

How can tactical analysis in soccer be conducted?

Traditionally, tactical analysis was conducted by coaches or specialized tactical analysts through observation, either on a field or via video footage, and it primarily involved qualitative elements [38]. With the introduction of notational analysis, written match reports began to incorporate statistical data, represented as performance indicators, which present frequency distributions of specific in-game events [7]. Combinations of these performance indicators can also be created, calculated by using mathematical operations [11]. However, while certain performance indicators provide valuable information, they are often insufficient to explain various aspects of team tactics [54]. Consequently, researchers shifted their focus to analyzing playing styles of teams that best exemplify tactical concepts [42]. Some developed observational tools [35], while others quantified playing styles by grouping disparate performance indicators obtained through statistical analyses, such as factor analysis [42].

The advent of tracking technologies has ushered in a significant revolution in tactical analysis [45]. These technologies enable simultaneous tracking of all players (as well as a ball), recording their positions on a field at every moment [39]. In addition to a capacity to create new performance indicators of significant value in tactical analysis (such as centroid, approximate entropy, outplayed opponents, and pressing index) [31], tracking technologies have also facilitated tactical analyses utilizing Voronoi diagrams [14]. Furthermore, another method for analyzing tactics that has gained traction in recent years involves an application of social network analysis. This approach allows an examination of passing patterns employed by teams during a possession phase [53].

Aim of Study

The application of AI methods in soccer tactical analysis marks a transformative juncture in the world of sports analytics. This narrative review aims to provide a comprehensive overview of the existing literature, highlighting methodologies, challenges, and potential implications of AI-driven soccer tactical analysis. By exploring real-world applications, challenges, and future directions, the aim is to contribute to understanding of how AI methods are reshaping soccer analysis, offering fresh perspectives on strategy formulation, player development, and the essence of the beautiful game.

Material and Methods

The literature search was conducted across the Scopus, Web of Science, and EBSCO databases on August 29th, 2023. To identify research articles written in English that applied AI techniques to derive insights into soccer

tactics, the following Boolean expression was employed: "((“ARTIFICIAL INTELLIGENCE” OR “MACHINE LEARNING” OR “NEURAL NETWORKS” OR “DEEP LEARNING”) AND “SOCCER” AND “TACTICS”)". This search aimed to collate studies that examined the intersection of advanced computational methods and tactical analysis within the realm of soccer. Articles that were not research-based, unpublished in scientific journals, book chapters, or conference proceedings, as well as articles written in languages other than English were excluded from selection.

Results

Initially, a total of 90 research articles written in English were found. After removing duplicates and articles referring to robotic soccer, 50 articles remained. Following a review of the abstracts of these 50 articles, another 27 were excluded for the following reasons: a) they studied other sports (other than soccer), b) they did not utilize AI techniques, c) they did not investigate issues related to tactics. The 23 articles that were ultimately used for the review are presented in Table 1, showing the article title, author, year of publication, purpose, and the AI method that was applied. The articles are listed in chronological order.

Discussion

The application of AI to tactical analysis in soccer

The integration of AI into tactical analysis in soccer has significantly advanced a capability to decipher complex game dynamics and enhance strategic decision-making. By synthesizing a wide range of methodologies from various studies, it becomes evident how AI not only captures, but also effectively predicts and influences soccer strategies. Early attempts to incorporate AI in soccer analysis, such as a study by Lucey et al. [32], focused on segmenting matches into manageable “play-segments” to study team behaviors through spatiotemporal tracings. This foundational work paved the way for more sophisticated techniques such as Self-Organizing Maps (SOMs) and Dynamically Controlled Networks (DyCoNs), which Grunz et al. [20] and Perl et al. [40] used to analyze player formations and behaviors, introducing a dynamic aspect to understanding player movements and team configurations. These techniques laid the groundwork for further exploration of team dynamics and players' roles, as demonstrated by Bialkowski et al. [5] and Knauf et al. [28], who employed data-rich analytics to dynamically evaluate team structures and formations using heat maps and probability density functions.

Table 1. Articles included in the review

Title	Author [reference]	AI technique	Objectives
Characterizing multi-agent team behavior from partial team tracings: evidence from the English Premier League	Lucey et al. [32]	k-Nearest Neighbor (kNN)	to analyze and characterize team behaviors based on predictability of their actions across different field areas
Tactical pattern recognition in soccer games by means of special self-organizing maps	Grunz et al. [20]	Artificial neural networks (Self-Organizing Maps [SOMs], including the Dynamically Controlled Network [DyCoN] extension)	to identify and classify tactical patterns in soccer games, such as different game initiations, based on positional data of players and a ball
Tactics analysis in soccer: an advanced approach	Perl et al. [40]	Artificial neural networks, specifically SOMs and DyCoN, combined with rule-based semantics analysis and statistical frequency analysis	to analyze and evaluate tactical patterns and game dynamics in soccer, incorporating pattern-based tactics analysis with success-oriented statistical analysis to improve understanding of tactical performance
Team activity recognition in Association Football using a Bag-of-Words-based method	Montoliu et al. [36]	Bag-of-Words (BoW) technique for video clips characterization, kNN, Support Vector Machine (SVM), Multilayer Perceptron (MLP), and Random Forest (RF)	to perform team activity recognition and analysis in association football, enabling automatic identification of team behaviors and actions such as ball possession, quick attack, and set piece, based on short soccer video clips without relying on player tracking
Discovering team structures in soccer from spatiotemporal data	Bialkowski et al. [5]	Linear Discriminant Analysis (LDA), k-Nearest Neighbor (kNN)	to learn soccer team formations from tracking data, align player tracking data to specific roles within a game, discover team structures, and predict team identity based on playing style

Spatio-temporal convolution kernels	Knauf et al. [28]	spatio-temporal convolution kernels, kernel methods, dynamic time warping, Gaussian Radial Basis Function (RBF) kernel, probability product kernel, multinomial mixture model, spectral clustering, k-medoids clustering, expectation maximization, Nyström method, silhouette measure, Hartigan index, Rand Index, Adjusted Rand Index	to capture similarities in multi-object scenarios, identify frequent patterns in multi-trajectory data, analyze multi-object trajectory data involving clustering tasks, and evaluate performance of clustering algorithms on artificial and real-world datasets
Classification of passes in football matches using spatiotemporal data	Chawla et al. [8]	SVMs, Logistic Regression (LR), and RUSBoost, Multinomial Logistic Regression (MLR), computational geometry	to classify quality of passes in soccer matches
Similarity calculation based on pass regions in soccer videos	Takahashi et al. [51]	Active Net, Deep Neural Network (DNN) based on visual feature extracted using the Inception-v3 model	to calculate similarity between soccer scenes in videos based on visualized pass regions, aiming for enhanced understanding and analysis of soccer tactics
Team tactics estimation in soccer videos based on a deep extreme learning machine and characteristics of the tactics	Suzuki et al. [50]	Deep Extreme Learning Machine (DELM)	to estimate team tactics in soccer videos based on players' formations and unique characteristics of the tactics
GreenSea: visual soccer analysis using broad learning system	Sheng et al. [48]	Recurrent Discriminative Broad Learning System (RDBLS), CNN (LeNet-5), DBNs, SAEs, SDA, Deep Boltzmann Machines (DBM), an Extreme Learning Machine (ELM)-based multilayer structure HELM, and MLP	to provide a system for quantitative analysis and visual summarization of soccer games, assisting coaches in performance assessment, player selection, and tactical decision-making based on comprehensive visual and statistical data analysis
Positional analysis of Brazilian soccer players using GPS data	Gasparini and Álvaro [16]	kNN, Decision Trees (DTs), LR, SVM, and Neural Networks (NNs)	to predict an ideal position of soccer players based on GPS data collected from Brazilian professional soccer players, enhancing tactical decision-making and positional analysis
Predicting wins, losses and attributes' sensitivities in the Soccer World Cup 2018 using neural network analysis	Hassan et al. [21]	RBFNN Model	to predict match outcomes (wins or losses) and determine sensitivity of match attributes affecting the outcomes in the 2018 FIFA World Cup
Process mining of football event data: a novel approach for tactical insights into the game	Kröckel and Bodendorf [29]	SOM clustering algorithm and Markov chain clustering	to analyze soccer event data for tactical insights, comparing performance and behavior between teams and players, and supporting decision-making in before, after, and during live games
DNN-based multi-output model for predicting soccer team tactics	Lee and Jung [30]	DNN based on MLP	to predict soccer team tactics, including formations, game styles, and game outcomes, using soccer datasets
Optimising long-term outcomes using real-world fluent objectives: an application to football	Beal et al. [2]	DNN	to optimise long-term tactical and strategic decision-making in soccer, enhancing teams' performance across a season by learning from past games and predicting future outcomes

Soccermap: a deep learning architecture for visually-interpretable analysis in soccer	Fernández and Bornn [13]	Fully Convolutional Neural Networks (FCNNs)	to estimate full probability surfaces of potential passes in soccer from high-frequency spatio-temporal data, allowing for fine-grained analysis of player positioning and decision-making
Technical and tactical command decision algorithm of football matches based on big data and neural network	Fang et al. [12]	Recurrent Neural Network (RNN), Standard RNN, Long Short-Term Memory Networks (LSTMs), SVM, SRC, LRC, LCCR, and RDBLS	to analyze big data from soccer competitions for predicting offensive and defensive tactics and to improve an algorithm for learning the timing of video data from soccer matches
The tactics of successful attacks in professional association football: large-scale spatiotemporal analysis of dynamic subgroups using position tracking data	Goes et al. [18]	Unsupervised Machine Learning (K-Means Clustering)	to automatically identify dynamic formations and subgroups based on position tracking data for analyzing spatio-temporal behavior in relation to successful attacks in professional soccer matches
Using machine learning pipeline to predict entry into the attack zone in football	Stival et al. [49]	Deep Convolutional Networks EfficientNetB0, DNN	to predict whether an attacking team will reach the fourth quarter of a soccer field (attacking zone), considering teams' movements during the first 5 seconds after a team takes control of a ball
Enhancements of pass play quantification method with geometric features of formations	Mimura and Nakada [34]	Gaussian Process Classification with RBF kernel functions, LR	to quantify pass plays in soccer using multiple geometric feature values from player position data, aiming to improve performance of models for quantifying effectiveness and risk of pass plays and enhancing visualization of quantification results
GOALALERT: A novel real-time technical team alert approach using machine learning on an IoT-based system in sports	Karakaya et al. [26]	Discriminant Analysis, kNN, Naive Bayes, SVM, DT, Ensemble Learning Methods (AdaBoost, Boosted Trees, RUSBoosted Trees, and Bagged Trees)	to provide real-time alerts and information to a technical team about likelihood of goal occurrences in a soccer match, utilizing tactical formation and other relevant data collected through IoT systems, with a goal of assisting in tactical decision-making during a match
Temporal match analysis and recommending substitutions in live soccer games	Berman et al. [4]	Forest DNN, RF, XGBoost, Time Series Forest (TSF), Column Concatenator Classifier (CCC), and RandOm Convolutional KErnel Transform (ROCKET), k-Means clustering	to identify an opponent team's tactics in a live soccer match and recommend substitute players based on on-field players' live game ratings
Prediction of defensive success in elite soccer using machine learning – Tactical analysis of defensive play using tracking data and explainable AI	Forcher et al. [15]	LR, XGBoost, RF	to predict successful vs unsuccessful defensive plays (ball gain vs no ball gain) and identify tactical variables that drive defensive success in soccer

The analytical power of AI was expanded by Montoliu et al. [36], who introduced the Bag-of-Words (BoW) technique to categorize video clips based on motion, enhancing granularity of play analysis. This method of dissecting visual data into quantifiable elements complements a positional and tracking data analysis conducted by Gasparini and Álvaro [16] and Berman et al. [4], where GPS and network metrics provided a detailed layer of tactical understanding, bridging a gap between raw data and strategic insights.

The progression in AI applications also extends to predictive analytics, where models developed by Sheng et al. [48] using the Recurrent Discriminative Broad Learning System, and Hassan et al. [21] using Artificial Neural Networks, illustrate the capacity of AI not only to analyze, but also to predict outcomes based on historical and real-time data. This predictive capability is crucial during matches, where strategic decisions need to be supported by rapid and accurate data interpretations.

Furthermore, the AI's role in enhancing real-time decision-making is emphasized in studies like those by Fernández and Bornn [13], who developed deep learning models to predict pass probabilities, and Fang et al. [12], who integrated video analytics with Recurrent Neural

Networks to assess player skills and game dynamics. These studies highlight how real-time data processing and AI-driven insights are becoming indispensable in modern sports tactics.

The tactical application of AI is not limited to player tracking and real-time analytics, but also extends to strategic management over seasons, as illustrated by Beal et al. [2], who modeled soccer team's performance over a season, incorporating evolving objectives and strategic adaptations. This long-term strategy modeling shows AI's potential not only in individual games, but over entire seasons.

In summary, the application of AI in soccer tactical analysis offers a multifaceted enhancement to understanding and strategizing in soccer. Each method, whether focused on positional tracking, pattern recognition, predictive modeling, or strategic simulation, contributes to a comprehensive framework that supports coaches and analysts in crafting superior game tactics and strategies. This evolution marks a significant shift from traditional analysis methods to an integrated, AI-driven approach in sports science.

Future directions for AI application in soccer tactics

The application of AI in soccer tactics is still in its nascent stages, and the potential for future development is vast. Several directions for future research and applications emerge, promising to further enhance our understanding and execution of tactical analysis in soccer.

Integration of Advanced AI and ML Models: Future studies could explore integration of more advanced AI models, such as reinforcement learning and generative adversarial networks, to simulate game scenarios and develop new tactical strategies. These models can help create highly adaptive tactics that learn and evolve based on an opponent's playing style.

Enhanced Player Performance Prediction: Utilizing AI to predict player performance in specific tactical setups could significantly improve team preparation. Future research might focus on developing models that can predict how well a player would perform in various tactical scenarios, considering factors like fatigue, psychological state, and historical performance against similar opponents.

Real-time Tactical Decision Support Systems: Developing AI-driven decision support systems that can provide real-time tactical recommendations during a match could be a game changer. Such systems would analyze live data feeds to suggest tactical adjustments, substitutions, and formations in response to unfolding match dynamics.

Augmented Reality (AR) and Virtual Reality (VR) for Tactical Training: Use of AR and VR in conjunction with AI can revolutionize tactical training and match preparation. By simulating match situations with real-world data, players and coaches can experience and practice tactical scenarios in a controlled, immersive environment.

Deeper Analysis of Opponent Tactics: Future applications of AI could involve more sophisticated analysis of opponents' tactics, using deep learning to identify patterns and tendencies that are not visible to a human eye. This could help develop more effective counterstrategies.

Predictive Analytics for Injury Prevention: Integrating AI with biomechanical and physiological data could enable a prediction of potential injuries based on tactical plays and workloads. This would allow better management of players' fitness and readiness, tailoring training, and match participation to minimize injury risks.

Ethical and Fair Use of AI in Tactics: As AI becomes more integrated into soccer tactics, there will be a growing need to establish ethical guidelines and fair play standards. Future research should address ethical implications of AI in sports to ensure that its application promotes fairness and integrity in a game.

By exploring these future directions, the application of AI in soccer tactics can lead to unprecedented levels of strategic depth, player development, and engagement with the sport. As the technology advances, so will the ability to harness AI for the betterment of soccer, both on and off a field.

Conclusions

Exploring the role of AI in soccer tactical analysis has revealed a compelling narrative of technological integration within the sport. This narrative review has critically analyzed the current literature to uncover the innovative ways in which AI is being used to revolutionize tactical analysis in soccer, demonstrating its potential to become an indispensable tool for coaches, analysts, and players alike.

The gathered evidence highlights AI's significant impact on match preparation and in-game decision-making, bringing a data-driven approach to strategy formulation. ML models, neural networks, and complex algorithms are now essential for interpreting vast arrays of data, leading to more informed and strategic decision-making. The inclusion of 23 relevant articles in this review underscores the diversity and depth of research in this emerging field.

Several key areas, where AI contributes to tactical analysis, have been identified: predictive analytics,

dynamic tactical planning, real-time adjustments during games and pattern recognition in playing styles. Each of these areas represents a leap forward in understanding and execution of soccer tactics, translating into actionable strategies and measurable performance improvements on a field.

Looking to the future, the potential applications of AI in soccer tactics are boundless. The continuous development of advanced AI models holds the promise of even more sophisticated tactical analysis tools. These advancements could pave the way for real-time tactical decision support systems, augmented and virtual reality applications for training, and deeper analyses of opponents' tactics.

Moreover, the integration of AI with player performance prediction models and injury prevention analytics represents a holistic approach to player management and team performance. Ethical considerations and fair use guidelines for AI in sports will also become increasingly important as the technology continues to infiltrate this space.

Therefore, this article significantly enriches the scientific literature by offering the comprehensive analysis of how AI is pioneering the future of tactical analysis in soccer. Through the detailed literature review, it bridges the gap between traditional tactical analysis methods and the cutting-edge capabilities introduced by AI, underscoring the transformative impact AI has on enhancing strategic decision-making, optimizing player performance, and fostering deeper understanding of game dynamics. By synthesizing the current research findings and outlining the potential future directions, this article not only sheds light on the current state of AI applications in soccer, but also sets the stage for future innovations. Thus, it contributes to a growing body of knowledge that positions AI as a central pillar in the evolution of soccer tactics, providing valuable insights for researchers, practitioners, and enthusiasts within the realm of sports analytics and beyond.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Abbas Q, Ibrahim ME, Jaffar MA. Video scene analysis: an overview and challenges on deep learning algorithms. Multimed Tools Appl. 2018;77(16):20415-20453. https://doi.org/10.1007/s11042-017-5438-7
2. Beal R, Chalkiadakis G, Norman TJ, Ramchurn SD. Optimising long-term outcomes using real-world fluent objectives: an application to football. arXiv preprint arXiv:210209469. 2021, 18 Feb. https://doi.org/10.48550/arXiv.2102.09469
3. Beal R, Norman TJ, Ramchurn SD. Artificial intelligence for team sports: a survey. Knowl Eng Rev. 2019;34:e28. https://doi.org/10.1017/S0269888919000225
4. Berman Y, Mistry S, Mathew J, Krishna A. Temporal match analysis and recommending substitutions in live soccer games. 2022 IEEE International Conference on Web Services (ICWS); 2022: IEEE. https://doi.org/10.1109/ICWS55610.2022.00066
5. Bialkowski A, Lucey P, Carr P, Matthews I, Sridharan S, Fookes C. Discovering team structures in soccer from spatiotemporal data. IEEE Trans Knowl Data Eng. 2016;28(10):2596-2605. https://doi.org/10.1109/TKDE.2016.2581158
6. Bunker R, Susnjak T. The application of machine learning techniques for predicting match results in team sport: a review. J Artif Intell Res. 2022;73:1285-1322. https://doi.org/10.1613/jair.1.13509
7. Carling C, Williams AM, Reilly T. Handbook of soccer match analysis: a systematic approach to improving performance. London: Routledge; 2007. https://doi.org/10.4324/9780203448625
8. Chawla S, Estephan J, Gudmundsson J, Horton M. Classification of passes in football matches using spatiotemporal data. ACM Trans Spat Algorithms Syst. 2017;3(2):1-30. https://doi.org/10.1145/3105576
9. Chowdhury M, Sadek AW. Advantages and limitations of artificial intelligence. Transportation research circular. 2012:n.pag.
10. Delgado-Bordonau JL, Mendez-Villanueva JA. Tactical periodization: a proven successful training model. SoccerTutor.com; 2018.
11. Đošić N. Razlike u posedima lopte, kontaktima sa loptom i kontakt indeksima osvajača medalja na svetskom fudbalskom prvenstvu 2010. godine / Differances in ball possessions, contacts with the ball and contact index of the medal winners on the World Championship 2010. Sports Sci Health. 2014;7(1):64-72. https://doi.org/10.7251/SSH1401064DJ
12. Fang L, Wei Q, Xu CJ. Technical and tactical command decision algorithm of football matches based on big data and neural network. Sci Program. 2021;1:5544071. https://doi.org/10.1155/2021/5544071
13. Fernández J, Bornn L. Soccermap: a deep learning architecture for visually-interpretable analysis in soccer. In: Dong Y, Ifrim G, Mladenić D, Saunders C, Van Hoecke S, editors. Machine learning and knowledge discovery in databases. Applied data science and demo track. ECML PKDD. Lecture Notes in Computer Science. 2020;

12461. Springer, Cham. https://doi.org/10.1007/978-3-030-67670-4_30
14. Fonseca S, Milho J, Travassos B, Araújo D. Spatial dynamics of team sports exposed by Voronoi diagrams. Hum Mov Sci. 2012;31(6):1652-1659. https://doi.org/10.1016/j.humov.2012.04.006
15. Forcher L, Beckmann T, Wohak O, Romeike C, Graf F, Altmann S. Prediction of defensive success in elite soccer using machine learning – Tactical analysis of defensive play using tracking data and explainable AI. Sci Med Footb. 2023:1-16. https://doi.org/10.1080/24733938.2023.2239766
16. Gasparini R, Álvaro A. Positional analysis of Brazilian soccer players using GPS data. Revista Brasileira de Computação Aplicada. 2020;12(3):16-32. https://doi.org/10.5335/rbca.v12i3.10234
17. Ghosh I, Ramasamy Ramamurthy S, Chakma A, Roy N. Sports analytics review: artificial intelligence applications, emerging technologies, and algorithmic perspective. Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery. 2023:e1496. https://doi.org/10.1002/widm.1496
18. Goes FR, Brink MS, Elferink-Gemser MT, Kempe M, Lemmink KA. The tactics of successful attacks in professional association football: large-scale spatiotemporal analysis of dynamic subgroups using position tracking data. J Sports Sci. 2021;39(5):523-532. https://doi.org/10.1080/02640414.2020.1834689
19. Gréhaigne J-F, Godbout P, Bouthier D. The foundations of tactics and strategy in team sports. J Teach Phys Educ. 1999;18(2):159-174. https://doi.org/10.1123/jtpe.18.2.159
20. Grunz A, Memmert D, Perl J. Tactical pattern recognition in soccer games by means of special self-organizing maps. Hum Mov Sci. 2012;31(2):334-343. https://doi.org/10.1016/j.humov.2011.02.008
21. Hassan A, Akl A-R, Hassan I, Sunderland C. Predicting wins, losses and attributes' sensitivities in the soccer World Cup 2018 using neural network analysis. Sensors. 2020;20(11):3213. https://doi.org/10.3390/s20113213
22. Herold M, Goes F, Nopp S, Bauer P, Thompson C, Meyer T. Machine learning in men's professional football: current applications and future directions for improving attacking play. Int J Sports Sci Coach. 2019;14(6):798-817. https://doi.org/10.1177/1747954119879350
23. Hewitt A, Greenham G, Norton K. Game style in soccer: what is it and can we quantify it? Int J Perf Anal Sport. 2016;16(1):355-372. https://doi.org/10.1080/24748668.2016.11868892
24. Jha D, Rauniyar A, Johansen HD, Johansen D, Riegler MA, Halvorsen P, et al. Video analytics in elite soccer: a distributed computing perspective. 2022 IEEE 12th Sensor Array and Multichannel Signal Processing Workshop (SAM); 2022. pp. 221-225: https://doi.org/10.1109/SAM53842.2022.9827827
25. Kamila MK, Jasrotia SS. Ethical issues in the development of artificial intelligence: recognizing the risks. Int J Ethics Syst. 2023. https://doi.org/10.1108/IJOES-05-2023-0107
26. Karakaya A, Ulu A, Akleylek S. GOALALERT: A novel real-time technical team alert approach using machine learning on an IoT-based system in sports. Microprocess Microsyst. 2022;93:104606. https://doi.org/10.1016/j.micpro.2022.104606
27. Kim JS, Merrill RK, Arvind V, Kaji D, Pasik SD, Nwachukwu CC, et al. Examining the ability of artificial neural networks machine learning models to accurately predict complications following posterior lumbar spine fusion. Spine. 2018;43(12):853. https://doi.org/10.1097/BRS.0000000000002442
28. Knauf K, Memmert D, Brefeld U. Spatio-temporal convolution kernels. Mach Learn. 2016;102:247-273. https://doi.org/10.1007/s10994-015-5520-1
29. Kröckel P, Bodendorf F. Process mining of football event data: a novel approach for tactical insights into the game. Front Artif Intell. 2020;3:47. https://doi.org/10.3389/frai.2020.00047
30. Lee GJ, Jung JJ. DNN-based multi-output model for predicting soccer team tactics. PeerJ Comput Sci. 2022;8:e853. https://doi.org/10.7717/peerj-cs.853
31. Low B, Coutinho D, Gonçalves B, Rein R, Memmert D, Sampaio J. A systematic review of collective tactical behaviours in football using positional data. Sports Med. 2020;50:343-385. https://doi.org/10.1007/s40279-019-01194-7
32. Lucey P, Bialkowski A, Carr P, Foote E, Matthews I. Characterizing multi-agent team behavior from partial team tracings: evidence from the English Premier League. Proceedings of the AAAI Conference on Artificial Intelligence; 2012. https://doi.org/10.1609/aaai.v26i1.8246
33. Memmert D, Rein R. Match analysis, big data and tactics: current trends in elite soccer. Dtsch Z Sportmed. 2018;69(3). https://doi.org/10.5960/dzsm.2018.322
34. Mimura T, Nakada Y. Enhancements of pass play quantification method with geometric features of formations. 2022 International Conference on Engineering and Emerging Technologies (ICEET); 2022. pp. 1-6. https://doi.org/10.1109/ICEET56468.2022.10007279
35. Mitrotasios M, Gonzalez-Rodenas J, Armatas V, Aranda R. The creation of goal scoring opportunities in professional soccer. Tactical differences between Spanish La Liga, English Premier League, German

Bundesliga and Italian Serie A. Int J Perform Anal Sport. 2019;19(3):452-465. https://doi.org/10.1080/24748668.2019.1618568
36. Montoliu R, Martín-Félez R, Torres-Sospedra J, Martínez-Usó A. Team activity recognition in Association Football using a Bag-of-Words-based method. Hum Mov Sci. 2015;41:165-178. https://doi.org/10.1016/j.humov.2015.03.007
37. Moustakidis S, Plakias S, Kokkotis C, Tsatalas T, Tsaopoulos D. Predicting football team performance with explainable AI: leveraging SHAP to identify key team-level performance metrics. Future Internet. 2023;15(5):174. https://doi.org/10.3390/fi15050174
38. Nelson LJ, Groom R. The analysis of athletic performance: some practical and philosophical considerations. Sport Educ Soc. 2012;17(5):687-701. https://doi.org/10.1080/13573322.2011.552574
39. Oliva-Lozano JM, Martín-Fuentes I, Granero-Gil P, Muyor JM. Monitoring elite soccer players physical performance using real-time data generated by electronic performance and tracking systems. J Strength Cond Res. 2022;36(11):3224-3228. https://doi.org/10.1519/JSC.0000000000004082
40. Perl J, Grunz A, Memmert D. Tactics analysis in soccer: an advanced approach. Int J Comput Sci Sport. 2013(12):33-44.
41. Plakias S. An integrative review of the game model in soccer: definition, misconceptions, and practical significance. Trends Sport Sci. 2023;30(3):85-92. https://doi.org/10.23829/TSS.2023.30.3-1
42. Plakias S, Kokkotis C, Moustakidis S, Tsatalas T, Papalexi M, Kasioura C, et al. Identifying playing styles of European soccer teams during the key moments of the game. J Phys Educ Sport. 2023;23(4): 878-890. https://doi.org/10.7752/jpes.2023.04111
43. Plakias S, Moustakidis S, Kokkotis C, Papalexi M, Tsatalas T, Giakas G, et al. Identifying soccer players' playing styles: a systematic review. J Funct Morphol Kinesiol. 2023;8(3):104. https://doi.org/10.3390/jfmk8030104
44. Plakias S, Moustakidis S, Kokkotis C, Tsatalas T, Papalexi M, Plakias D, et al. Identifying soccer teams' styles of play: a scoping and critical review. J Funct Morphol Kinesiol. 2023;8(2):39. https://doi.org/10.3390/jfmk8020039
45. Plakias S, Tsatalas T, Moustakidis S, Kalapotharakos V, Kokkotis C, Papalexi M, et al. Exploring the influence of playing styles on physical demands in professional football. Hum Mov. 2023;24(4):36-43. https://doi.org/10.5114/hm.2023.133919
46. Rein R, Memmert D. Big data and tactical analysis in elite soccer: future challenges and opportunities for sports science. SpringerPlus. 2016;5(1):1-13. https://doi.org/10.1186/s40064-016-3108-2
47. Riboli A, Semeria M, Coratella G, Esposito F. Effect of formation, ball in play and ball possession on peak demands in elite soccer. Biol Sport. 2021;38(2):195-205. https://doi.org/10.5114/biolsport.2020.98450
48. Sheng B, Li P, Zhang Y, Mao L, Chen CP. GreenSea: visual soccer analysis using broad learning system. IEEE Trans Cybern. 2020;51(3):1463-77. https://doi.org/10.1109/TCYB.2020.2988792
49. Stival L, Pinto A, Andrade FdSPd, Santiago PRP, Biermann H, Torres RdS, et al. Using machine learning pipeline to predict entry into the attack zone in football. PloS ONE. 2023;18(1):e0265372. https://doi.org/10.1371/journal.pone.0265372
50. Suzuki G, Takahashi S, Ogawa T, Haseyama M. Team tactics estimation in soccer videos based on a deep extreme learning machine and characteristics of the tactics. IEEE Access. 2019;7:153238-153248. https://doi.org/10.1109/ACCESS.2019.2946378
51. Takahashi S, Bertini M, Del Bimbo A, Haseyama M, Hagiwara T. Similarity calculation based on pass regions in soccer videos. 2019 IEEE 8th Global Conference on Consumer Electronics (GCCE); 2019. pp. 515-516. https://doi.org/10.1109/GCCE46687.2019.9015352
52. Teoldo I, Guilherme J, Garganta J. Football intelligence: training and tactics for soccer success. Routledge; 2021. https://doi.org/10.4324/9781003223375
53. Wäsche H, Dickson G, Woll A, Brandes U. Social network analysis in sport research: an emerging paradigm. Eur J Sport Soc. 2017;14(2):138-165. https://doi.org/10.1080/16138171.2017.1318198
54. Winter C, Pfeiffer M. Tactical metrics that discriminate winning, drawing and losing teams in UEFA Euro 2012®. J Sports Sci. 2016;34(6):486-492. https://doi.org/10.1080/02640414.2015.1099714