Real-Time Tactical Analysis: Leveraging GNSS Position Data for Tactical Behavior

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Abstract: In team sports such as football, tactical analysis has become essential to evaluate the collective behavior of the team and provide immediate and reliable feedback to the coaching staff. Global navigation satellite system (GNSS) tracking systems are widely used in team sports such as football. From geographic coordinates (e.g., latitude and longitude), information about the positions of players during a match can be obtained. Most GNSS-based systems use location tracking information to evaluate physical performance in terms of external load and physical stress. This research aims to present a technological innovation called GLF (Geo Live Football), which integrates tactical measures from raw GNSS data to understand the behavior of the team during matches, introducing the concept of "live" analysis.

1 INTRODUCTION

In team sports, performance analysis has become an essential tool for coaches, athletes, sports organizations, and researchers. Collecting and interpreting performance data allows coaches to improve training programs, athletes to make better tactical decisions, sports organizations to manage teams more effectively, and researchers to develop a better understanding of sports performance. Analysis can include technical, metabolic, and tactical aspects, providing a comprehensive view of player performance (O'Donoghue 2015). In invasive sports such as soccer, key actions are observed, recorded, and analyzed through subjective observation, resulting in the loss of relevant information (Franks 1991). The application of technology in sports has enabled automatic monitoring of player performance during play. Automated physical performance monitoring helps to define the movement characteristics of elite soccer players during matches (Lago-Peñas 2012), quantify training load (Buchheit 2013), emphasize athletes' movement during match activities, and provide a systematic approach to working with elite players (Strudwick 2013). Over time, research has highlighted an increasing correlation between variables associated with physical performance and tactical behaviors in soccer. It has been studied how strategic decisions, collaborative actions between players, positioning in relation to the game situation, off-ball movements, passing choices, and interaction with other players influence overall performance on the pitch (Low, 2020). Tactical analysis in elite soccer has historically relied on observational data using variables that discount most of the contextual information. Team tactical analysis requires detailed data from various sources, including technical ability, individual physiological performance, and team formations (Rein 2016). Recent performance analysis is increasingly connected to Big Data (Memmert 2018), defining new approaches to calculate metrics that help measure and especially identify team and individual performance of players, the way teams interact, thus reducing the gap between research, data collection, and their interpretation and use (Carling 2005). This evolution allows a more precise vision of reality, providing information on the strengths and weaknesses of one's team and opponents in various phases of the game (Castellano 2012).

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2 USE OF POSITIONAL DATA IN FOOTBALL

Football teams are increasingly using microtechnology, incorporating GPS to monitor physical conditions by quantifying the external load (EL) in terms of total distance traveled, various speed thresholds, accelerations/decelerations and composite variables (Silva 2018; Rago 2020; Brink and Frencken 2018). This application often leaves out significant information, especially in the investigation and evolution of team tactical behavior and the individual and collective actions that a team organizes to score a goal and win the match. A study (Sampaio and Macas 2012) investigated how the dynamics of player positional data from GNSS systems could be used to assess tactical behavior by measuring movement patterns and coordination between players, opening new research horizons and reducing the gap between sports science and sports training. The research addressed in this article proposes the development of a technological system "Geo Live Football" (GLF), which integrates and develops tactical metrics (**Figure 1**), and introduces the concept of "live", offering a complete and real-time vision of the physical and tactical behavior of the team during matches.

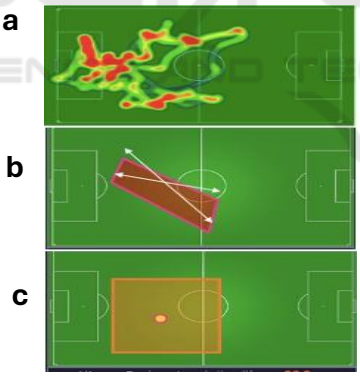

Figure 1: (A, B, and C), include team CG, team aspect ratio, team heatmap, and team effective playing area.

3 GNSS - SYSTEM REQUIREMENTS

GNSS-based performance monitoring systems have been widely used in recent years to analyze the performance of sports teams, such as in football, by providing detailed information during training and matches-play. However, football clubs are constantly looking for improvements. Analyzing live tactical behavior during matches, using tactical metrics, presents a new challenge. Real-time information about players' physical condition and overall team performance statistics, obtained by geolocalization players on the pitch, are essential for making decisions and strategic adjustments during matches. GNSS is a key technology for tracking and monitoring athlete performance. Compared to its main alternative, Ultra-Wide-Band technology, it does not require ground infrastructure near the football pitch. Most football stadiums are not fully covered, and those that are use materials such as polytetrafluoroethylene (PTFE) or glass fiber composites, or ETFE (ethylene tetrafluoroethylene), which minimize GNSS signal attenuation. To provide real added value to live football applications, GNSS systems must ensure:

- High Accuracy: At least 50cm RMS for tactical purposes, achievable using real-time differential corrections and dual-frequency receivers.
- Miniaturization: Devices should be small enough to integrate into undergarments, impacting battery and antenna size.
- Integration with Accelerometers: To better calculate key performance parameters like metabolic power.
- Low Power Consumption: Necessary due to dual-frequency receivers and real-time transmission power requirements. At least 4 hours of autonomy is required.
- Real-Time Data Transmission: Low-power and customized transmission protocols to reduce power consumption and avoid packet collisions. The typical RF interference in football stadiums should be considered. The transmission medium will be a 4G/5G modem encapsulating RTCM V3.1 or V3.2/MSM (Multiple Signal Messages) standard for differential correction.
- Real-Time Data Processing: To derive specific metrics.
- An app for configuration and metric viewing.

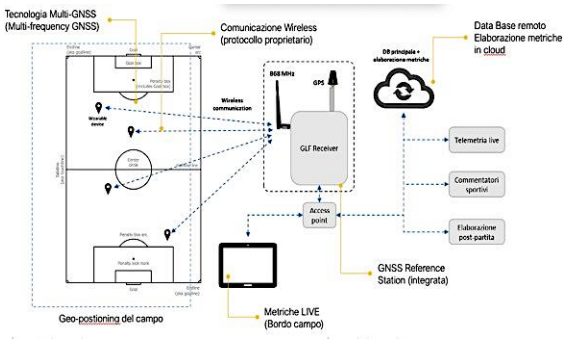

Figure 2: Operational architecture.

4 GEO LIVE SOCCER SYSTEM

The proposed application, GLF (GeoLiveFootball), represents an innovative tool for "live" real-time monitoring of football performances. Currently, athlete performance monitoring does not use players' positions for tactical analysis, which is primarily conducted through video analysis at additional costs. GLF enables both performance and tactical analysis within the same solution. GLF, a downstream application of PNT User Segment (GNSS) technology, allows "live" metrics calculation, usable by coaching staff for match tactics analysis with accurate positioning, player geolocation, and real-time data collection and processing (Figure 3). Accurate PVT of each wearable GNSS device will be calculated using differential corrections from a GNSS reference station; PVT will then be transferred to a cloud server. The software can select differential corrections from available commercial services (e.g., HxGN SmartNet, Trimble RTX) or a reference station provided by GLF. The GLF metrics calculation software on the cloud server will provide a general overview of team performance in geometric terms and individual players' physical and technical performance (distance indicators and kinematics such as speed, intensity, and acceleration) at predefined intervals (usually 5 minutes). Metrics will be available through a web-based interface for controlled user access and system setup for each football club (Figure 3). The GLF metrics will aid coaching staff in decision-making during matches, and all metrics are recorded for post-match analysis. GLF evolved from the MESSI-HP solution (Monitoring Evolution with Soccer Satellite Navigator Innovation - High Precision) developed to monitor players during training and competitions. GLF's innovative features include:

- **Live:** Real-time GNSS data transmission and processing, providing real-time metrics during events, a unique feature in match analysis solutions.
- **High Accuracy:** Target placement accuracy of about 50cm error, comparable to UWB accuracy, enabling game tactics evaluation.
- **Georeferencing:** GNSS devices are used for kinematic purposes (velocity, acceleration, metabolic power). GLF georeferences player positions relative to the football field, providing insight into player positions during matches and being competitive with UWB and video analytics, which are not "live".
- **Miniaturization:** Devices are extremely miniaturized, fitting in a bib pocket. Key design features include:
- **Multi-Constellation** and dual-frequency GNSS receiver (e.g., ublox F9P)
- **Transmission** of GNSS signal phase difference corrections (RTCM V3.x) RTK and DGNSS algorithms for high accuracy positioning (RMS <50cm)
- **Hybridization** of GNSS and IMU data
- **4G/5G data transmission**

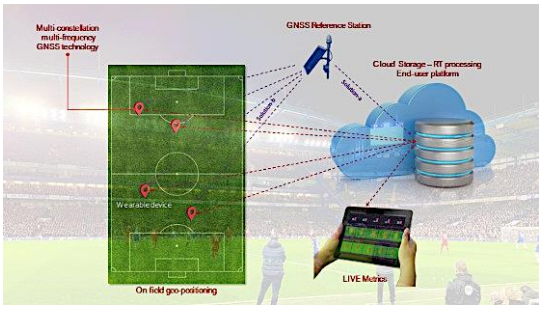

Figure 3: Tactical metrics visible through a web-based interface.

4.1 Georeferencing: Four Corners of the Field

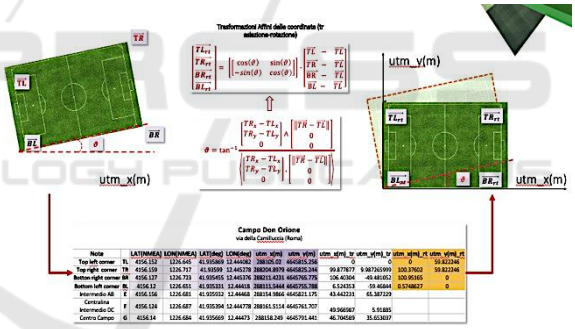

Figure 4: Pitch location: four pitch corners.

Georeferencing is crucial for accurate player positioning during a game. This is done by visually determining the four corners of the field and manually obtaining the latitude and longitude coordinates by clicking on those corners.

4.2 Live Match

The match session allows detection of both physical and technical-tactical metrics during training or official matches and viewing only some metrics. Technical-tactical metrics are aimed at the team, while physical metrics target individual players, groups, or the entire team. During live matches, data is displayed at 5-minute intervals. The metrics chosen to be displayed during the live session include:

4.2.1 Real-Time Tactical Metrics

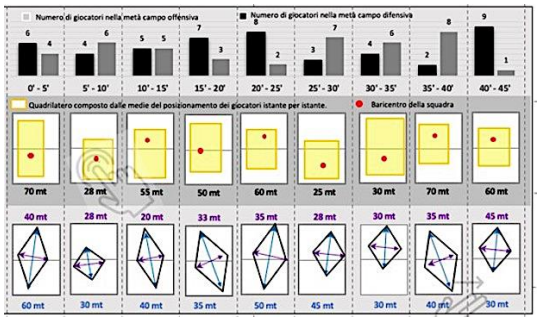

Figure 5: Players who occupy the offensive and defensive phase, Center of gravity of the team, Heat map, Team length and width, Occupied playing area.

Tactical metrics (**Figure 5**) offer an overview of how the team moves on the pitch and are particularly useful for analyzing the formation and collective behavior during the most important phases of the game, such as attack and defense. This information allows you to refine strategies in real time, favoring greater tactical effectiveness.

- **Players involved in the offensive and defensive phases:** this metric highlights the number of players who participate in the attack and defense phases. It is an important indicator for evaluating the balance of the team and identifying any tactical imbalances.
- **Team Center of Gravity:** represents the geometric point that corresponds to the average value of the spatial distribution of players on the field, providing information on the overall structure of the team. This metric allows you to evaluate whether the team tends to lean too much towards attack or to remain excessively compact in defense.
- **Heat Map:** graphically represents the areas of the field most occupied by players. This visualization is useful for identifying which areas are used most frequently and which areas are under-used, providing fundamental information to optimize field coverage and implement strategies.
- **Team Length and Width:** these metrics measure how much the team extends on the field, both in terms of depth (length) and width (width). Length concerns the distance between the most advanced players and those furthest back, while width describes the use of lateral spaces. This information helps to evaluate whether the team is too compact or too dispersed.
- **Occupied Playing Area:** defines the space covered by the team during the various phases of the game. It is used to determine the team's ability to effectively cover the pitch and limit the spaces available to opponents.

4.2.2 Real-Time Physical Metrics

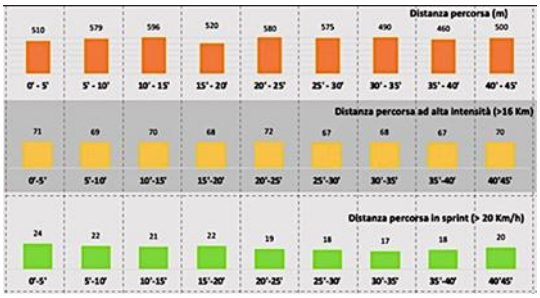

Figure 6: Total distance traveled, distance traveled at high intensity, distance covered in sprints.

Physical metrics (**Figure 6**), on the other hand, focus on individual player performance, monitoring parameters such as endurance, speed and intensity. This data is essential to understand the physical state of players during the match and to make informed decisions regarding substitutions or changes of pace.

- **Total distance traveled:** measures the total number of kilometers covered by an individual player or the entire team during the match. It is an indicator of physical endurance and can be useful for assessing levels of fatigue.
- **High-intensity distance traveled:** calculates the distance covered by players at high speed. This metric is crucial for analyzing physical effort during the most intense moments of the game, such as during pressing or counterattacks.
- **Sprint distance traveled:** shows the distance covered at maximum speed. This metric is important for evaluating the acceleration capacity of players and their contribution during decisive moments, such as rapid offensive or defensive actions.

5 USING METRICS DURING THE GAME

Analyzing physical and tactical metrics at regular intervals, such as every 5 minutes, provides a real-time overview of team and individual player performance. Tactical metrics allow you to assess the team's position on the pitch and make immediate

strategic adjustments. In contrast, while physical metrics allow you to monitor fatigue levels and optimize substitutions or changes of pace. Together, this data is a powerful tool for making quick, informed decisions during the game, improving your chances of success.

6 DISCUSSION

In the discussion section, it is essential to compare and contextualize the GLF system with other similar technologies to highlight its distinctive features and the specific contributions it offers to the field of sports analytics. Here is how we can integrate the Catapult Sports and STATSports systems into the comparison. The GLF system represents significant advances in the field of sports performance analytics, especially when compared to existing technologies. For example, Catapult Sports and STATSports are widely used systems that use Global Navigation Satellite System (GNSS) technology to track player movements and measure performance in real time. These systems rely on GPS data to evaluate physical metrics such as speed, distance and acceleration, while also offering tools for tactical analysis. However, the GLF system stands out for its ability to provide “live” data in real time, allowing teams to make tactical adjustments during matches, a feature that represents a significant improvement over the post-match analysis offered by traditional systems. While systems like Catapult and STATSports are more focused on monitoring physical performance, the GLF system integrates both physical and tactical metrics with superior accuracy. With a margin of error of approximately 50 cm, the GLF provides a higher level of accuracy than many GNSS-based platforms currently available. This superior accuracy translates into more detailed and actionable information to improve tactical performance. Additionally, the GLF’s real-time geotagging capabilities rival other solutions, such as Ultra-Wideband (UWB) and video analytics, but with the added benefit of providing immediate feedback, essential for making in-game adjustments. Another area where the GLF excels is the miniaturization of GNSS devices, designed to fit discreetly into a chest pocket without compromising player performance. Featuring multi-constellation, dual-frequency receivers, these devices represent a more technologically advanced solution than those typically employed by systems like Catapult and STATSports, which tend to use bulkier, less sophisticated hardware. By integrating these features—high accuracy, real-time data processing, and advanced miniaturization—the GLF system addresses some of the most critical challenges in sports analytics, such as data accuracy, stadium coverage, and efficient data management. Compared to established systems like Catapult and STATSports, the GLF offers a more comprehensive solution for analyzing both physical and tactical performance, marking a significant advancement in the way team dynamics and in-game strategies are evaluated.

7 CONCLUSIONS

This research presented an innovative system leveraging GNSS technology to capture and analyze players' positional data during matches. By integrating these data into tactical metrics, the system offers a comprehensive evaluation of both physical and tactical performance. The "live" analysis capability of the GLF system represents a significant advancement in sports analytics. For this system to be reliable and accurate, it must adhere to specific technical requirements. The GLF system meets these standards, ensuring precise and real-time data collection, which is crucial for detailed tactical performance evaluation and future tactical planning.

REFERENCES

O'Donoghue, P. 2015. Introduction to Sports Performance Analysis, Routledge.

Franks, I.M. & Miller, G. 1991. Training Coaches to Observe and Remember. Sports Science Journal, 9, 285-297.

Lago-Peñas, C., Rey, E. & Lago-Ballesteros, J. 2012. The influence of actual playing time on the physical demands of elite soccer players. The Open Sports Science Journal, 5.

Buchheit, M., Racinais, S., Bilsborough, J.C., Bourdon, P.C., Voss, S.C., Hocking, J., Cordy, J., Mendez-Villanueva, A. & Coutts, A.J. 2013. Monitoring fitness, fatigue, and run performance during a pre-season training camp in elite soccer players. J Sci Med Sports, 16, 550-5.

Sampaio, J.E., Lago, C., Goncalves, B., Macas, V.M. & Leite, N. 2014. Effects of rhythm, state, and imbalance in motion variables of tempo, heart rate, and tactical behavior during soccer play to 5 small row games. Journal of Science and Medicine in Sports, 17, 229-33

Strudwick, A. 2013. Contemporary issues in the physical preparation of elite players. Science and Football. Routledge.

Low, B., Coutinho, D., Goncalves, B., Rein, R., Memmert, D. & Sampaio, J. 2020. A systematic review of

collective tactical behaviors in soccer using positional data. Sports Medicine, 50, 343-385.
Rein, R. & Memmert, D. 2016. Big data and tactical analysis in elite football: future challenges and opportunities for sports science. Springer Plus, 5, 1410.
Memmert, D. & Rein, R. 2018. Match Analysis, Big Data and Tactics: Current Trends in Elite Football. Deutsche Zeitschrift Fur Sportmedizin, 2018, 65-72.
Carling, C., Williams, A.M. & Reilly, T. 2005. Handbook of Soccer Match Analysis a Systematic Approach to Improving Performance, London; Routledge.
Castellano, J., Casamichana, D. & Lago, C. 2012. The use of match statistics discriminating between successful and unsuccessful soccer teams. Journal of Human Kinetics, 31, 139-47.
Silva, P., Santos, E.D., Grishin, M. & Rocha, J.M. 2018. Validity of heart rate-based indices for measuring training load and intensity in elite soccer players. Journal of Strength and Conditioning Research, 32, 2340-2347.
Clemente, F., Couceiro, M., Martins, F. & Mendes, R. 2013. An online tactical metric applied to the game of soccer. Research Journal of Applied Sciences, Engineering and Technology, 5, 1700-1719.
Shergill, A.S., Twist, C. & Highton, J. 2021. Importance of GNSS data quality assessment with new control criteria in professional soccer matches. International Journal of Performance Analysis in Sports, 21, 820-830.