Goal-Line Technology

SEMINAR REPORT

Submitted by

MIDHUN AK

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DECLARATION

I hereby declare that the seminar report "**Goal-Line Technology** ", submitted for partial fulfillment of the requirements for the award of degree of Master of Computer Applications of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of **Mrs.Remmya CB**. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree.

Place: Kallanthode   MIDHUN AK

Date: 27/03/2023

CERTIFICATE

This is to certify that the report entitled "**Goal-Line Technology**" submitted by **MIDHUN AK (KMC21MCA-2014)**, to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Master of Computer Applications is a bonafide record of the seminar work carried out by him under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Internal Supervisor   Seminar Coordinator

                                                                Head Of The Dept

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ABSTRACT

Goal-line technology is a system that has been implemented in football to assist referees in more accurately determining whether or not a goal has been scored. The system notifies the referee via a smartwatch or other device when the ball crosses the goal line using cameras and sensors. This technology has been introduced to help reduce the number of mistakes made by referees and to provide a fairer way of making decisions.Goal line technology systems come in a variety of forms, including camera-based and sensor-based systems. Multiple high-speed cameras are positioned around the goal in camera-based systems to take pictures of the ball as it crosses the line. When the ball has fully crossed the line, sensor-based systems use pressure sensors that are placed inside the ball or in the goalpost.Goal line technology has been introduced to many major football leagues around the world, including the English Premier League, and the Spanish La Liga. The system has been well-received by fans and players, with many praising its ability to provide a more accurate and fairer way of making decisions.

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Chapter 1

Introduction

Goal-line technology is a system used in football (soccer) to determine whether the ball crossed the goal line resulting in a goal. The technology uses a combination cameras and sensors to determine exactly whether the entire ball has crossed the line the implementation of goal-line technology was a response to controversial refereeing decisions, where it was difficult for the referee to determine whether the ball had crossed the line. It led to much debate and controversy among players, coaches and fans, as well as the potential for unfair results in important matches. Goal-line technology has been successfully used in major football competitions around the world, including the English Premier League, UEFA Champions League and FIFA World Cup. The system proved to be accurate and reliable, providing quick and convincing results that eliminate any doubts or debates on whether a goal has been scored.Overall, goal-line technology has improved significantly fairness and accuracy of football matches and has become an essential tool for ensuring integrity of sport.

1.1   General Background

Goal-line technology has now become an established part of professional football matches around the world. This technology is used to determine whether the ball has completely crossed the goal line and if a goal was scored. There are different types goal-line technology systems currently in use, including camera systems systems and sensor-based systems. These systems work by capturing footage in real time position and movement of the ball and use computer algorithms to analyze this data and determine if a goal has been scored. Many major football leagues and competitions, including the English Premier League, La Liga, Serie A, Bundesliga and UEFA Champions League have adopted the goal-line technology in recent years. This technology was also used in the FIFA World Cup since 2014.

Overall, goal-line technology has proven to be a reliable and effective way to ensure this football match results are fair and accurate. Technology has decreased significantly disputes and controversies surrounding the decision on the goal, and became an essential tool for referees and officials in professional football matches. As such, the goal line is likely the technology will continue to be used in sports for years to come.

Chapter 2

Evolution of Goal-Line Technology

The evolution of GLT can be traced back to the 20th century, when several technologies were devised to help referees make accurate decisions. One of the earliest forms of GLT was the use of video playback, which was first proposed in the 1960s. However, due to the limitations of the technology at the time, it was not practical to implement this system. It wasn't until the 1990s that the idea of using cameras and computer analysis to determine whether a goal had been scored caught on.

In 2004, British company Hawk-Eye Innovations developed the GLT system, which used cameras placed around the goal posts to track the position of the ball. The system was first used in a competitive match in 2007 during the Club World Cup in Japan. The technology was later adopted by the English Premier League in 2013 and has since been used in major football competitions such as the World Cup and the UEFA Champions League.

Another GLT system that appeared around the same time was GoalRef, which used magnetic fields to determine whether the ball had crossed the goal line. This system was developed by a German-Danish company and was tested in the Danish Superliga in 2012.

However, the system was not widely adopted due to concerns about its reliability and cost.

In 2012, FIFA announced that it would use GLT in a major international competition for the first time, at the 2014 World Cup in Brazil. Two GLT systems, Hawk-Eye and GoalControl, were selected for use in the tournament. GoalControl used 14 high-speed cameras mounted around the stadium to track the ball's position and determine if it had crossed the goal line.

Chapter 3

Challenges of Referee

The objective of goal-line technology is not to replace the role of the offi cials, but rather to support them in their decision-making due to the speed of the game and their position on the field of play.

One of the difficulties referees face is that the human eye can only process about 16 images per second, which means the ball must be behind the line for at least 60 milliseconds. However, occasionally the ball is only briefly behind the line before a player kicks it back or it bounces back into the field of play, making it impossible for the human eye to determine whether the ball has crossed the line. Nowadays, players are able to shoot at speeds of over 120 km/h,whereas the ball can only be seen by the human eye at speeds of 12 km/h or less.

Another challenge is the vantag point. When viewed from certain angles, it is easy to misjudge the ball's position. Cameras placed at different angles can mislead viewers when showing images "proving" whether or not the ball has crossed the line, which is why only technology dedicated to evaluating such incidents can support the referee in the decision-making process and contribute to a fair game.
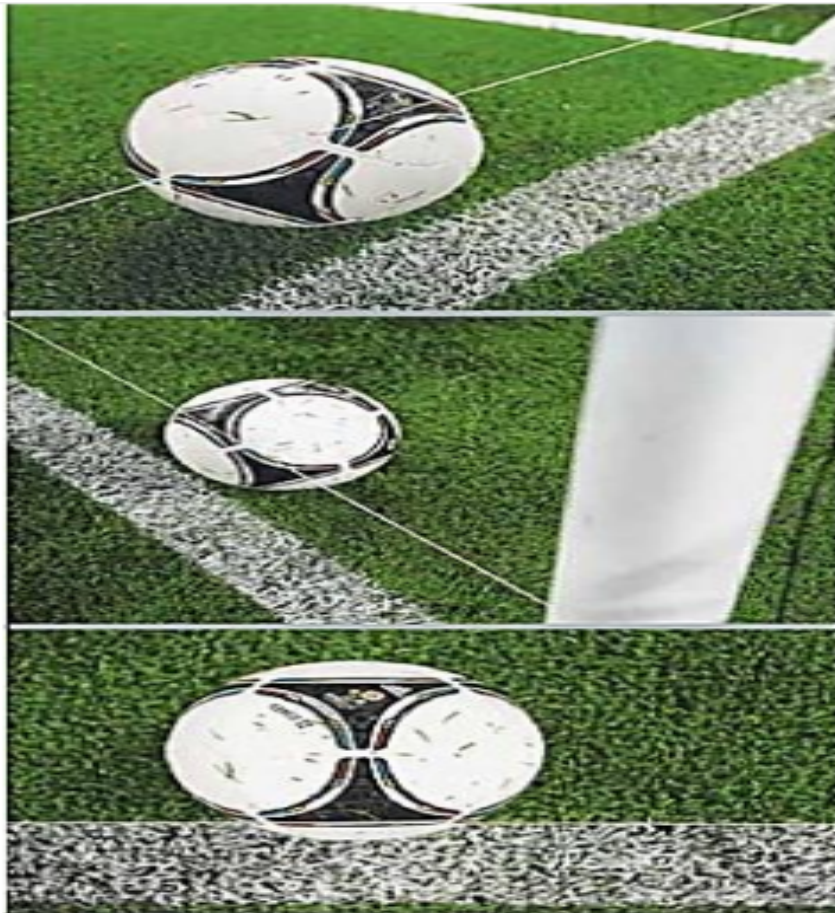
Figure 3.1: One situation, different perceptions

Chapter 4

Methods In Goal-Line Technology

Methods In Goal-Line Technology can be classified into two types

4.1 Hawk–Eye

Hawkeye's system can track the ball's position to within a few millimeters, allowing it to determine whether or not the ball has completely crossed the goal line. If the system detects that the ball has crossed the line, it sends a signal to the referee's watch that a goal has been scored.

Hawkeye technology is used in a variety of sports, including cricket and tennis, and is becoming increasingly common in top-flight football. The technology has been praised for its accuracy and ability to quickly and objectively determine whether or not a goal has been scored, reducing the possibility of human error or controversy.

In short, Hawkeye technology in football uses high-speed cameras and computer software to track the ball's position and determine its trajectory. It is widely used in top-flight football matches and has become an important tool for referees in determining whether or not a goal has been scored.

Figure 4.1: Hawk-eye System

4.2 GoalRef

Goal referee technology in soccer is a system used to determine whether the ball has crossed the goal line or not. It uses a combination of magnetic fields and radio waves to track the ball's position and determine whether or not it has completely crossed the goal line.

The system works by placing a set of antennas around the goal posts and crossbar. These antennas generate a magnetic field around the goal area. A small chip is inserted into the ball, which emits a radio signal when it comes into contact with a magnetic field. The antennas then pick up the signal and transmit it to a computer that can determine the position of the ball relative to the goal line.

If the system detects that the ball has completely crossed the goal line, it will send a signal to the referee's watch that a goal has been scored. The system is designed to be highly accurate, with a deviation of less than one centimeter.

Goal ref technology has been used in a number of football tournaments, including the 2012 FIFA Club World Cup. The technology has been praised for its accuracy and reliability, and has been seen as a valuable addition to the sport, reducing the possibility of human error or controversy.

In short, goal referee technology in soccer uses a combination of magnetic fields and radio waves to track the ball's position and determine whether or not it has completely crossed the goal line. The system is highly accurate and has been used in a number of soccer tournaments, helping to reduce the potential for human error in determining whether or not a goal has been scored.

Figure 4.2: 6 GoalRef Attachment

4.3   Cairos GLT system

It uses four major components

1.Magnetic Field

Magnetic fields are a key component of some goal-line technology systems used in football. These systems use a combination of magnetic fields and radio waves to track the ball's position and determine if it has completely crossed the goal line. The magnetic field is created by placing a set of antennas around the goal posts and crossbar. These antennas generate a magnetic field around the goal area. A small chip is inserted into the ball, which emits a radio signal when it comes into contact with a magnetic field. The antennas then pick up the signal and transmit it to a computer that can determine the position of the ball relative to the goal line. One of the advantages of using magnetic fields in goal line technology is that they can be used in all weather conditions, including rain or snow. Unlike some camera systems, magnetic fields are not affected by changes in lighting conditions or other environmental factors.

2. Sensors

Sensors are a vital part of many of the goal-line technology systems used in football. These systems use various sensors to track the ball's position and determine if it has completely crossed the goal line. Some of the more common types of sensors used in goal line technology include:

Camera sensors: Many goal-line technology systems use high-speed cameras to capture images of the ball as it moves toward the goal line. These cameras can capture multiple images per second, which are then analyzed by computer software to determine the exact

position of the ball.

Magnetic Sensors: Some goal-line technology systems use magnetic sensors to track the position of the ball. These systems work by generating a magnetic field around the goal area that is detected by a small chip embedded in the ball. The ball's position can then be determined based on the strength and direction of the magnetic field.

Pressure Sensors: Some goal-line technology systems use pressure sensors built into the goal line to detect when the ball has completely crossed the line. These sensors can detect even the slightest change in pressure and can therefore provide a highly accurate indication of when a goal has been scored.

Radio Frequency Identification (RFID) Sensors: RFID sensors are another common type of sensor used in goal line technology. These sensors work by placing small RFID chips in the ball, which emit a radio signal when they come in contact with a sensor located on the goal posts or crossbar. The position of the ball can then be determined based on the timing and strength of the radio signal.

3. Receivers

In camera-based goal-line technology systems, receivers are typically placed around the goal area to receive signals from high-speed cameras. These cameras capture multiple images of the ball per second, which are then transmitted to receivers for analysis. Receivers help ensure that the signals sent by the cameras are received accurately and reliably, which is essential for accurate ball tracking.

In sensor-based goal-line technology systems, receivers are used to receive signals from various sensors, such as magnetic sensors or RFID sensors. These sensors are usually

embedded in the ball or placed around the goal area and transmit signals to receivers when the ball crosses the goal line. The receivers then transmit these signals to a computer for analysis, which allows the system to determine whether a goal has been scored.

The design and placement of receivers is a critical factor in the accuracy and reliability of goal-line technology systems. Receivers must be positioned to receive signals from all areas of the goal area and must be able to filter out any interference or noise that could affect the accuracy of the signals. In addition, the receivers must be designed to withstand the elements and any physical impacts that may occur during the match.

Overall, receivers are a key part of the goal line technology systems used in football. They make it possible to receive signals from cameras or other sensors and transfer them to a computer for analysis, which is necessary to accurately track the ball and determine whether a goal has been scored.

4. Referee

Goal-Line Technology (GLT) has revolutionized the way referees decide whether a goal has been scored or not. GLT systems use various sensors and cameras to track the position of the ball and determine if it has completely crossed the goal line. Arbitrators play an important role in the implementation of GLT as they are responsible for making the final decision based on the information provided by the technology.

Referees are trained to use GLT technology and have access to the system during matches. The technology is designed to be easy to use and referees can quickly check if a goal has been scored using a watch or other device connected to the GLT system. The system provides clear and definitive information on whether the ball has completely

crossed the goal line, reducing the possibility of human error or controversy.

While GLT has made it easier for referees to make accurate decisions regarding goal-line incidents, it is important to note that referees still play an important role in the game. Referees are responsible for upholding the rules of the game and must use their judgment and experience to make decisions regarding fouls, penalties and other incidents that occur during the match.

Figure 4.3: Cairos GLT system

Figure 4.4: GoalRef Antenna behind the goal

Chapter 5

Implementation of goal-line technology

5.1   Cost Calculation:

The cost of implementing goal-line technology (GLT) in football can vary depending on the system chosen, the number of stadiums to be equipped and the level of technology required. Here are some of the factors that can affect the costing of a target technology:

System cost:

The cost of the GLT system itself is likely to be the biggest expense. There are different systems available, each with their own costs, features and requirements. For example, Hawk-Eye, one of the most commonly used systems.

Installation cost:

Installing the system can also be a significant expense as it requires special equipment and expertise. The price will depend on the size and complexity of the stadium, the type of system installed and the time required to complete the installation.

Maintenance cost:

Once the system is installed, ongoing maintenance costs will be incurred to ensure that it continues to operate efficiently. This may include the cost of replacing parts, upgrading software, and performing regular inspections and tests.

Training cost:

Referees, assistant referees and other officials will need training to use the GLT system effectively. The cost of this training may include the development of training materials, the hiring of trainers, and the time and expense required to train officials.

5.2 Installatioin:

Choose the appropriate goal-line technology:

The first step is to select the appropriate technology that will work best for the stadium. Some of the technologies available include magnetic field systems, camera-based systems, and chip-in-ball systems. It is important to consider the accuracy, reliability and cost-effectiveness of each technology before making a final decision.

Prepare the stadium:

The next step is to prepare the stadium for the technology installation. This includes assessing the stadium's infrastructure and making any necessary upgrades or modifications to accommodate the technology. For example, it may be necessary to install cameras in strategic positions around the goal area.

Install the technology:

Once the stadium is ready, the technology can be installed. This is the installation of

specialized cameras or sensors in the goal area. For camera systems, the cameras must be installed at the correct height and angle to ensure accurate data. For systems with a magnetic field, it is necessary to install magnetic strips below the goal line.

Test the technology:

After installation, the technology needs to be tested to make sure it works properly. This includes running simulations of ball trajectories and checking that the technology accurately detects when the ball has crossed the goal line. The testing process may take days or even weeks to complete.

5.3   Education of Referees:

Understand the technology:

The first step for referees is to clearly understand how goal-line technology works. This includes knowing the type of technology used in the stadium and how it provides information about whether the ball has crossed the goal line or not. Referees need to know the capabilities and limitations of technology in order to make informed decisions.capabilities and limitations to make informed decisions.

Practice using the technology:

Referees must be familiar with the use of technology during a match. They should practice using the technology during training and pre-match briefings to learn how to use the technology. Referees should be trained in how to interpret the data provided by the

technology and how to make quick and accurate decisions based on the data.

Communication:

Communication is essential in a football match and referees should be trained to communicate effectively with the personnel responsible for operating the goal line technology. Referees must know how to request the use of technology during a game, how to interpret data, and how to communicate decisions to players and other officials.

Refresher training:

Referees must receive regular refresher training to ensure they are up-to-date on any updates or changes in technology. This includes training on any new technology or protocols that are introduced and reviewing past decisions made using that technology.

Figure 5.1: Training Section of Referees

Chapter 6

Applications of Goal-Line Technology

6.1 Determining whether a goal has been scored:

The primary application of goal line technology is to determine whether or not a goal has been scored. This technology is used to track the position of the ball and determine if it has completely crossed the goal line. If the technology determines the ball has crossed the line, it sends a signal to the referee's watch that a goal has been scored.

6.2 Resolving disputes:

Goal-line technology can be used to resolve disputes about whether or not a goal has been scored. There have been cases in the past where referees have incorrectly ruled whether a ball has crossed the line, leading to controversy and disputes between teams. Goal-line technology can help avoid these controversies by providing an objective and accurate assessment of whether a goal has been scored.

6.3 Improving the accuracy of refereeing decisions:

The use of goal-line technology can help improve the accuracy of refereeing in soccer matches. Referees are under a lot of pressure to make quick decisions in high pressure situations and mistakes can happen. Goal-line technology can help reduce the potential for human error and ensure that the right decision is made.

6.4 Enhancing the spectator experience:

The use of goal line technology can improve the spectator experience by giving fans a clear and accurate view of whether a goal has been scored. This can help increase the excitement and drama of matches as fans can be sure that the right decision has been made.

Chapter 7

Advantages of Goal-Line Technology

1. Increased accuracy:

   GLT ensures the correct decision in situations where it is difficult for the referee to determine whether the ball has crossed the goal line. This helps eliminate human error and reduces the likelihood of controversial decisions.

2. Improved fairness:

   GLT ensures that goals are awarded or denied fairly, without bias or subjective interpretation. This increases the integrity of the game and helps promote a level playing field for all teams.

3. Quick and reliable:

   GLT provides real-time information to the referee, enabling fast and reliable decision-making. This reduces the amount of time wasted on questionable decisions and helps keep the game running smoothly.

4. Non-invasive:

   GLT is non-invasive and does not disrupt the game in any way. The technology is

designed to work in the background and not disrupt the player or the flow of the
game.

5. Easy to understand:

   GLT is easy to understand and provides clear evidence of whether a goal has been
   scored or not. This makes it easier for players, coaches, and fans to understand the
   decisions made by the referee.

6. Enhances the spectator experience:

   GLT adds to the excitement of the game by providing clear evidence of scoring
   opportunities. It also helps reduce the frustration and anger that can arise from
   controversial decisions.

Chapter 8

Challenges of goal-line technology

1. Technical problems:

   GLT systems may experience technical difficulties such as camera or sensor malfunctions, power outages or connectivity issues. These problems can lead to delays or incorrect decisions, which can affect the outcome of the match.

   :

   GLT systems can be expensive to implement and maintain, especially for smaller clubs or leagues with limited resources. This can create an uneven playing field as some teams may have better access to technology than others.

2. Limitation in scope:

   GLT only applies to situations where the ball has crossed the goal line and does not deal with other areas of the game where controversial decisions may occur, such as offside calls or penalty decisions.

3. Human error:

   Although GLT is designed to reduce the impact of human error on referee decisions,

there is still a risk that errors will occur. Referees may misinterpret data provided by

technology or be influenced by other factors such as crowd pressure or bias.

Chapter 9

Future Enhancements Of Goal-Line Technology

Goal line technology has already been implemented in many major football leagues around the world and has proven to be a valuable tool in ensuring accurate decisions are made as to whether or not a goal has been scored. However, there are still areas where new research technologies could be used to improve goal line technology even further. Here are some examples:

Artificial Intelligence (AI) and Machine Learning (ML):

The use of artificial intelligence and ML is being developed to improve the accuracy of goal line technology. These technologies can be used to analyze data from cameras and sensors to produce more accurate and faster results.

Multiple Camera Systems:

Currently, most goal technology systems use a single camera, but multiple camera systems are being developed to increase accuracy. Multiple cameras can capture the position of the ball from different angles, improving the system's ability to determine if the ball has crossed the goal line.

Wearable Technology:

Wearable technology such as smart watches or sensors can be used to improve the accuracy of goal line technology. These devices can track player movements and provide data on whether the ball has crossed the goal line.

Cloud-based technology:

Cloud-based technology is being developed to provide access to finish line technology data from anywhere in the world. This technology can be used to analyze data from multiple matches, providing insight into player performance, team strategies and more.

Semi-automated offside technology:

Semi-automated offside is a new research technology that could help referees make more accurate decisions when it comes to determining whether a player is in an offside position or not. Currently, offside decisions are made by assistant referees who run along the touchline trying to keep up with the players. However, this can be a difficult and subjective task and it is not always clear whether a player is offside or not.

The semi-automatic offside technology involves the use of cameras and artificial intelligence algorithms to track the position of players on the pitch. The system would use computer vision to identify when a player is in an offside position and then use a smart watch or other device to alert the assistant referee.

The system is "semi-automated" because it would still require a human referee to make the final decision based on the information provided by the technology. The idea behind this approach is to provide the referee with more accurate information and reduce the risk of human error.

There are several challenges involved in developing a semi-automated offside technology system, including the need to account for the curvature of the pitch and the potential for errors in the camera tracking system. However, if these challenges can be overcome, semi-automatic offside technology could have a significant impact on the accuracy and fairness of offside decisions in football.

Robotic referee assistant

Offside calls have come under increasing scrutiny in recent years, with VAR seemingly causing more problems in the Premier League than it solves. A VAR (Video Assistant Referee) is a match official who uses video footage to review the referee's decisions. VAR has left fans disappointed on various occasions, such as footballers being caught offside by – for example – their armpits, even though the rest of their bodies were well on. To solve these challenges, FIFA is considering a new approach: the use of robots. Because the sports organization plans to implement technology in the future of football. One of the systems under consideration is the Tracab program. The technology uses artificial intelligence-driven ball tracking combined with limb tracking and skeletal modeling. "Tracab can determine the exact moment of the critical pass of the ball and the exact position of the players involved and their limbs relative to the goal line," the referee's robotic assistant system automatically creates lines and sends alerts in case of an offside position, the video assistant can view (offside) game situations much faster.

Smart Stadiums:

Smart stadiums are equipped with advanced technology such as Wi-Fi, sensors and cameras that can be used to provide fans with a more immersive experience. For example, fans can

use their mobile devices to access real-time stats and scores, or even order food and drinks

without leaving their seats.

Chapter 10

Conclusion

In conclusion, goal-line technology has had a significant impact on football by improving the accuracy and fairness of refereeing decisions. The system has been introduced to many major football leagues around the world and has been well-received by fans and players. Goal-line technology uses cameras and sensors to detect when the ball has crossed the goal line, and then alerts the referee via a smartwatch or other device. There are several different types of goal-line technology systems, including camera-based and sensor-based systems.

Although there are still some challenges associated with goal-line technology, such as ensuring that the system is reliable and affordable for smaller clubs and leagues, the benefits of this technology are clear. It has reduced the number of mistakes made by referees, which has led to a more accurate and fairer way of making decisions. As technology continues to advance, we can expect to see further developments in goal line technology and other technologies designed to improve the accuracy and fairness of refereeing decisions in football.

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