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ORIGINAL

Technological assistance in highly competitive sports for referee decision making: A systematic literature review

Asistencia tecnológica en deportes de alta competencia para la toma de decisiones arbitrales: Una revisión sistemática de literatura

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ABSTRACT

Introduction: during the last decade, it has become evident that the impact of a referee's decision in professional sports turns out to be a turning point in the outcome of a competition, often generating discomfort among fans and competitors. It is for this reason that technological assistants were implemented in sports to help in referee decision making.
Objective: review and analyze those technological solutions based on the use of artificial intelligence techniques capable of serving as technological assistants in support of referee decision-making in highly competitive professional sports.
Method: the PICO methodology was used for the selection process of scientific publications of the PRISMA declaration. Finding 21 scientific publications extracted from the SCOPUS database that comply with the proposed guidelines, which were reviewed and analyzed to obtain information with added value.
Results: it was found that the proposed technological assistants reached a level of precision greater than 90 % in certain sports. Likewise, those limitations were found that reduce the operational quality of these solutions. As found those algorithms, models, methods and approaches of artificial intelligence most used and recommended for future research studies.
Conclusions: in conclusion, the implementation of technological assistants based on artificial intelligence in referee decision making in professional sports has proven to be an effective tool, achieving significant levels of precision.

Keywords: Technological Assistants; Arbitration Decisions; Artificial Intelligence; Decision Making.

RESUMEN

Introducción: durante la última década, se ha evidenciado que el impacto de la decisión de un árbitro en el deporte profesional, resulta ser un punto de inflexión en el desenlace de una competencia, generando en muchas ocasiones molestias entre los aficionados y competidores. Es por este motivo, que se procedió a implementar asistentes tecnológicos en el deporte para ayudar en la toma de decisiones arbitrales.
Objetivo: revisar y analizar aquellas soluciones tecnológicas basadas en el uso de técnicas de inteligencia artificial capaces de fungir como asistentes tecnológicas en apoyo a la toma de decisiones arbitrales en deportes profesionales de alta competencia.
Método: se usó de la metodología PICO y para el proceso de selección de publicaciones científicas de la declaración PRISMA. Encontrándose, 21 publicaciones científicas extraídas de la base de datos SCOPUS, que cumplen con los lineamientos propuestos, los cuales, fueron revisadas y analizados para la obtención de información con valor agregado.
Resultados: se constató que los asistentes tecnológicos propuestos alcanzaron un nivel de precisión mayores al 90 % en determinados deportes. De igual modo, se encontró aquellas limitaciones que merman la calidad operativa de estas soluciones. Como se encontró aquellos algoritmos, modelos, métodos y enfoques de inte

ligencia artificial más usados y recomendados para futuros estudios de investigación.
Conclusiones: en conclusión, la implementación de asistentes tecnológicos basados en inteligencia artificial en la toma de decisiones arbitrales en deportes profesionales ha demostrado ser una herramienta efectiva, alcanzando niveles de precisión significativos.

Palabras clave: Asistentes Tecnológicos; Decisiones Arbitrales; Inteligencia Artificial; Toma de Decisiones.

INTRODUCCIÓN

In recent times, the level of impact of the referee's decision in professional sports has been confirmed, turning out to be a point of vital importance in the outcome of a competition, often generating discomfort among collaborators and sports fans, as a result of plays controversial, where an erroneous decision is made, as a result of the human and technological limitations that exist, thus producing a decrease in the quality of the game, which is why the idea of having technological assistants capable of operate as support for referees in decision making. Thus, technological solutions have been progressively implemented by the organizations that govern the different sports disciplines. On the other hand, in recent times, there has been an exponential increase in the use of artificial intelligence to solve complex situations and its incorporation into the sports field, with cases where it allows managing large volumes of information, with respect to certain behavioral patterns of athletes efficiently, as well as measuring the performance of players and predicting some ailments and/or risks of injuries. Thus, we have cases of implementation of technological assistants in various sports disciplines such as cricket and tennis, where tracking cameras are used to analyze the trajectory of the ball and verify if the ball remained in the game or left the game. Likewise, in basketball and American football, there is access to videos of automatic replays of incidents to evaluate decision-making during games.[1] Likewise, the beautiful sport has also been affected by technology, from the year 2016, in the celebration of the club world cup, making use of the popular and controversial Video Assistant Referee (VAR), which was built with the purpose of reducing and/or mitigating those human errors inherent to refereeing and minimizing the impact of these decisions in the results of football matches by Kubayi et al.[2], thus preventing scenarios such as the one that occurred in the final of the 1966 World Cup, at Wembley Stadium, London, where, in overtime and with a tied score of 2-2, between England and Germany, the English striker Geoff Hurst shot at the German goal, hitting the upper crossbar and bouncing over the goal line. Faced with this situation, referee Gottfried Dienst awarded the goal, despite not be totally sure of what happened, changing the procedure of the match completely, concluding the match 4-2, in favor of England.[3] However, with VAR implemented, unfortunate incidents have occurred, such as in the Qatar World Cup, where, throughout the tournament, controversial penalties were charged to the Argentina team, which reaffirms Tamir & Bar's position. -eli, in “The moral gatekeeper: soccer and technology, the case of video assistant referee (VAR)”, where it is emphasized that the implementation of the VAR in soccer will serve as an assistant in decision-making in cases of Controversial plays, however, will not completely eliminate refereeing errors, since, for a sports judgment, human intervention is required.

Once the use of these technological tools and certain controversies in sport have been described, the dilemma arises, in different sectors, regarding the permanence of their use in current sporting events, the question being whether in reality the technological assistants used produce accurate results. and suitable for making an adequate judgment regarding incidents in real-time encounters as in certain cases presented.

In view of the constant discussion on the issue previously raised in different sectors, making use of different approaches, through investigating research articles found in databases such as Scopus, in fields of communication sciences and life sciences computing, the relevance of the topic today is determined.

Likewise, the systematic review "The Controversy of Sports Technology" by Dyer[4] was taken as a starting point, to expand the information referred to, since the article dates back to 2015, being outdated, excluding for periodic reasons, the evaluation of systems and models supported by emerging technologies by Dyer[4] such as machine learning and/or Deep learning, used for the optimization of software of different types, through the entry of data or previous experiences.[5] In addition, it has an approach more associated with the field of communication sciences than technology. For this reason, an update of knowledge about the technological tools used in sport is appropriate, which is why a Systematic Literature Review is proposed to evaluate the results of systems and models based on emerging technologies used as technological tools in different sports disciplines, with the aim of concluding with the ambivalence, dichotomy and uncertainty generated by the use of these resources. Likewise, in this review, we aim to understand and record the current panorama of emerging technological solutions for the sports field.

Thus, the objective of this review lies in being able to review and analyze those technological solutions based on the use of artificial intelligence techniques capable of serving as technological assistants in support of referee decision-making in highly competitive professional sports, to Thus, being able to have fairer sporting

events.

In relation to the structure of the systematic literature review, it consists of the following sections: section 1, the methodology and statement used for the search and selection process of research articles are presented, thus finding the research questions, criteria of inclusion and exclusion as a graphical representation of the study selection process. In section 2, the results are found, after having extracted and analyzed the most relevant data from the filtered research articles. In section 3, there is the discussion section, where the interpretation of the analyzed results is carried out, in order to reflect a synthesized panorama with respect to the value provided by these technological solutions. Finally, in section 4, the respective conclusions were developed, where the most relevant ideas and the main key points to improve in future research studies are mentioned.

METHODOLOGY

In the systematic review of literature presented, PICO is used, which is a methodology that allows the generation of structured review questions, through specific components, these being Problem or Object of Study (P), Intervention (I), Comparison(C), Result(O), Context(C), Time Interval(T). It should be noted that depending on the study scenario, the corresponding components will be used.

Based on this, it was proposed as a review question: what has been the level of precision of the technological assistants proposed for the issuance of precise judgments for sports arbitration in the different sports disciplines? This question arises from the need to know if These solutions turn out to be effective for future implementation and use in sporting events, in turn having derivations from the primary PICO question, these being:

Table 1. Derivations of the primary PICO question

PR.2	What has been the number of scientific publications found per year?
PR.3	What is the highly competitive sport with the greatest presence in scientific publications?
PR.4	What solution approaches have been the most used for the development of technological assistants?
PR.5	What artificial intelligence techniques have been most used by technological assistants to help decisions issued by sports arbitration in highly competitive sports?
PR.6	What artificial intelligence approaches have been most used for the development of technological assistants?
PR.7	What types of artificial intelligence architectures have been the most used for the development of technological assistants?
PR.9	What types of artificial intelligence models have been most used for the development of technological assistants?
PR.9	What types of artificial intelligence algorithms have been most used for the development of technological assistants?

Once the PICO question was defined, based on the components used, the appropriate keywords were identified.

Once the key words were defined in relation to each component used, the following search equation was generated: (TITLE-ABS-KEY(decision OR “Matching recognition” OR “Error recognition” OR “Decision making” OR “Real-time detection” OR “Video-assisted refereeing” OR var OR “Fault detection” OR “video assistant referee” OR “video assisting refereeing system” OR “Decision support systems” OR “Decision error indicator” OR “Ball tracking” OR “player tracking”) AND TITLE-ABS-KEY(ai OR “artificial intelligence” OR “Deep residual network” OR “machine learning” OR “deep learning” OR “neural network” OR “bayesian network” OR convolutional) AND TITLE-ABS-KEY(referee OR umpire OR judge) AND TITLE-ABS-KEY(soccer OR football OR sport OR volleyball OR tennis OR basketball)).

The generated search equation was applied in the Scopus database, obtaining 62 results, concerning the topic raised.

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Table 2. PICO question

Components		Compositions	Keywords
P	Problem/ Object of study	Technological assistants	decision OR "Matching recognition" OR "Error recognition" OR "Decision making" OR "Real-time detection" OR "Video-assisted refereeing" OR var OR "Fault detection" OR "video assistant referee" OR "video assisting refereeing system" OR "Decision support systems" OR "Decision error indicator" OR "Ball tracking" OR "player tracking"
I	Intervention	Artificial intelligence techniques	ai OR "artificial intelligence" OR "Deep residual network" OR "machine learning" OR "deep learning" OR "neural network" OR "bayesian network" OR convolutional
O	Results	Judgments issued by sports arbitration	referee OR umpire OR judge
C	Context	Different sports disciplines	soccer OR football OR sport OR volleyball OR tennis OR basketball

Having applied the search equation to Scopus, the selection process began. To do so, a search was used based on the PRISMA statement, which is a methodology focused on the systematic selection of literature, based on protocols, standards and exclusion and inclusion criteria, to obtain quality, reliable and accurate studies. The exclusion criteria that have been developed are the following:

Table 3. Exclusion criteria

CE.1	Research articles such as conference reviews and review articles will not be taken into consideration.
CE.2	Research articles in which machine learning techniques are applied for purposes that differ from arbitration assistance will not be taken into consideration.
CE.3	Research articles found prior to the period 2014-2023 will not be taken into consideration.
CE.4	Those research articles where technological solutions to the problems identified in sporting events have not been proposed will not be taken into consideration.
CE.5	Those research articles that propose technological solutions without techniques related to artificial intelligence will not be taken into consideration.

On the other hand, the following are the inclusion criteria:

Table 4. Inclusion criteria

CI.1	Original research articles, conference papers and book chapters will be considered.
CI.2	Research articles in languages, Spanish and English will be taken into consideration.
CI.3	Those research articles that apply artificial intelligence techniques focused on identifying incidents during sporting events will be taken into consideration.

Having defined the required criteria, the selection process begins, consisting of 4 phases. Firstly, the automatic filters of the Scopus database are used, supported by the exclusion criteria (CE.1 & CE.3), obtaining 13 research articles excluded for not meeting the criteria used, obtaining 49 articles, that they met the established criteria. Secondly, with the remaining 49 articles, the titles, keywords and summaries are reviewed, excluding a total of 5 articles and leaving a total of 44 research articles. Thirdly, a search process was carried out for the remaining full-text articles, a total of 9 articles could not be recovered and 35 research articles were recovered. Finally, an exhaustive review of the full-text research articles was carried out in depth, applying in turn the remaining exclusion and inclusion criteria, obtaining a total of 14 excluded articles and leaving a total of 21 selected research articles. to be used as part of the systematic literature review. This prism flow is described graphically through the following graph:

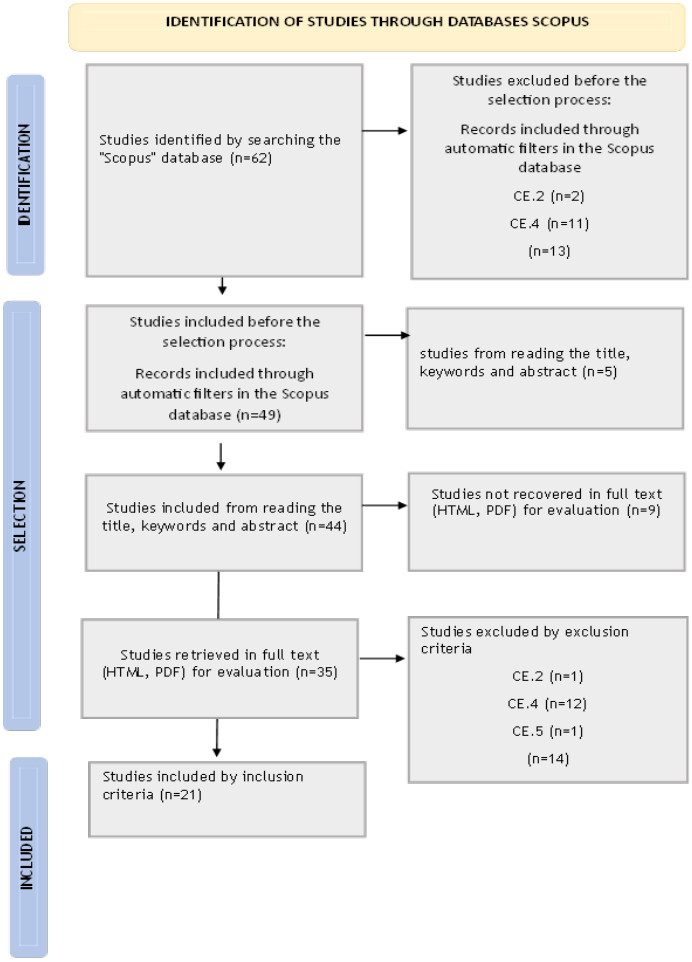

Figure 1. PRISM flow

RESULTS

Based on the discovery and selection of review articles obtained for the systematic literature review, the results are analyzed. Having defined the article extraction period 2015 – 2023, a total of 21 research articles were found, where a greater presence of conference papers was evident compared to other categories of scientific publications. Likewise, a greater number of scientific publications were found in 2020, compared to the others.

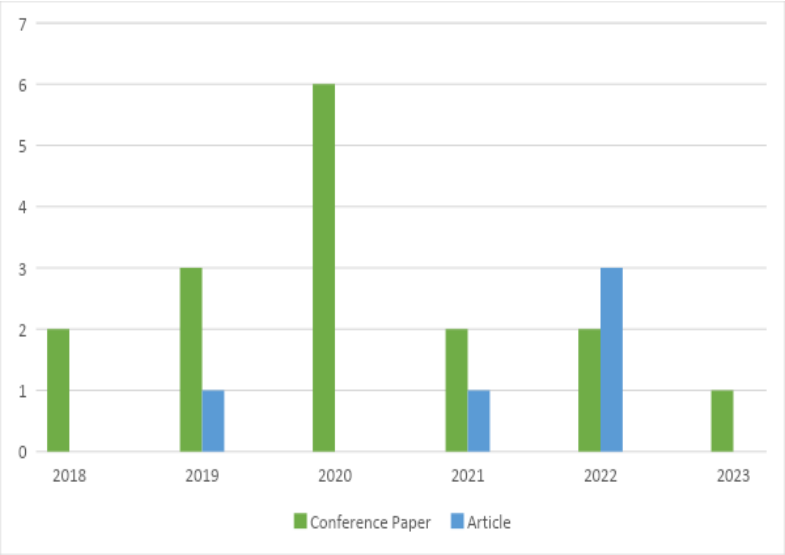

Figure 2. Number of scientific publications from the period 2015 – 2023

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Table 5. Number of scientific publications from the period 2015 – 2023 by categories

Authors	Category	Year	2018	2019	2020	2021	2022	2023
Matsuyama et al.[6]	Conference Paper	2023						✓
Suzuki et al.[7]	Conference Paper	2022					✓	
Mili et al.[8]	Conference Paper	2022					✓	
Jiang et al.[9]	Article	2022					✓	
Nandyal et al.[10]	Article	2022					✓	
Lu et al.[11]	Article	2022					✓	
Nandyal et al.[12]	Conference Paper	2021				✓		
Xu et al.[13]	Conference Paper	2021				✓		
Pan et al.[14]	Article	2021				✓		
Panse et al.[15]	Conference Paper	2020			✓			
Jiang et al.[16]	Conference Paper	2020			✓			
Voeikov et al.[17]	Conference Paper	2020			✓			
Iyer et al.[18]	Conference Paper	2020			✓			
Sunal et al.[19]	Conference Paper	2020			✓			
Abdullah et al.[20]	Conference Paper	2020			✓			
Kowsher et al.[21]	Conference Paper	2019		✓				
Ravi et al.[22]	Conference Paper	2019		✓				
Khan et al.[23]	Article	2019		✓				
Kamble et al.[24]	Conference Paper	2019		✓				
Shahjalal et al.[25]	Conference Paper	2018	✓					
Reno et al.[26]	Conference Paper	2018	✓					

Likewise, a greater number of research articles were found, focused on the implementation of technological solutions to Cricket, in contrast to other popular sports such as soccer, tennis and/or basketball.

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Table 6. Scientific publications by Sport

	Sports										
Authors	**Hockey**	**Race Walking**	**Cricket**	**Soccer**	**Tennis**	**Fencing**	**Skateboarding**	**Figure skating**	**Wu-Shu**	**Handball**	**Basketball**
Matsuyama et al.[6]								✓			
Suzuki et al.[7]		✓									
Mili R et al.[8]			✓								
Jiang Y et al.[9]	✓										
Nandyal et al.[10]			✓								
Lu et al.[11]									✓		
Nandyal et al.[12]			✓								
Xu et al.[13]										✓	
Pan et al.[14]											✓
Panse et al.[15]				✓							
Jiang et al.[16]					✓						
Voeikov et al.[17]					✓						
Iyer et al.[18]			✓								
Sunal et al.[19]						✓					
Abdullah et al.[20]							✓				
Kowsher et al.[21]			✓								

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Ravi et al.[22]	✓		
Khan et al.[23]	✓		
Kamble et al.[24]		✓	
Shahjalal et al.[25]	✓		
Reno et al.[26]			

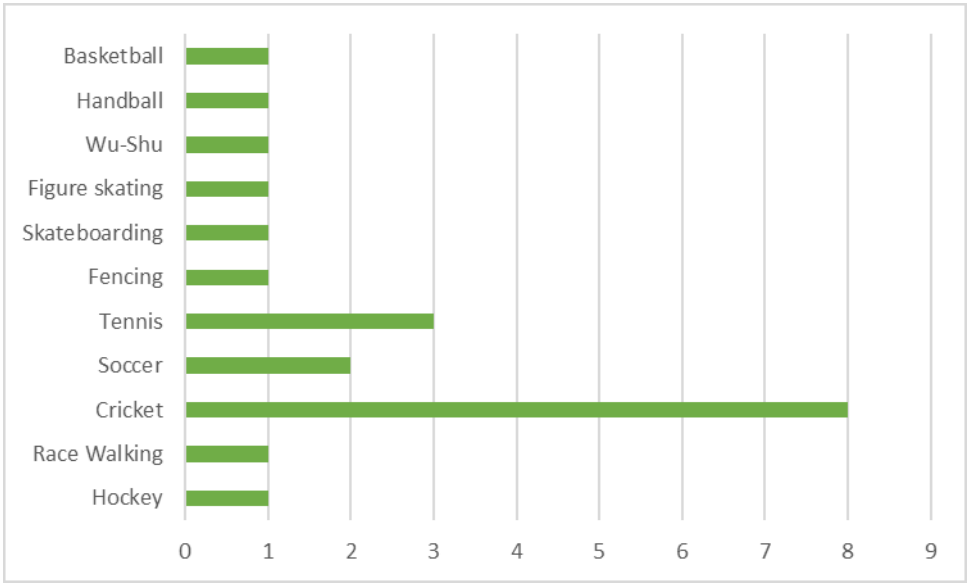

Figure 3. Number of scientific publications

this, in order to achieve precise decision making and a fair game, through event detection by having automated approaches for the detection and monitoring of players, balls and referee movements.

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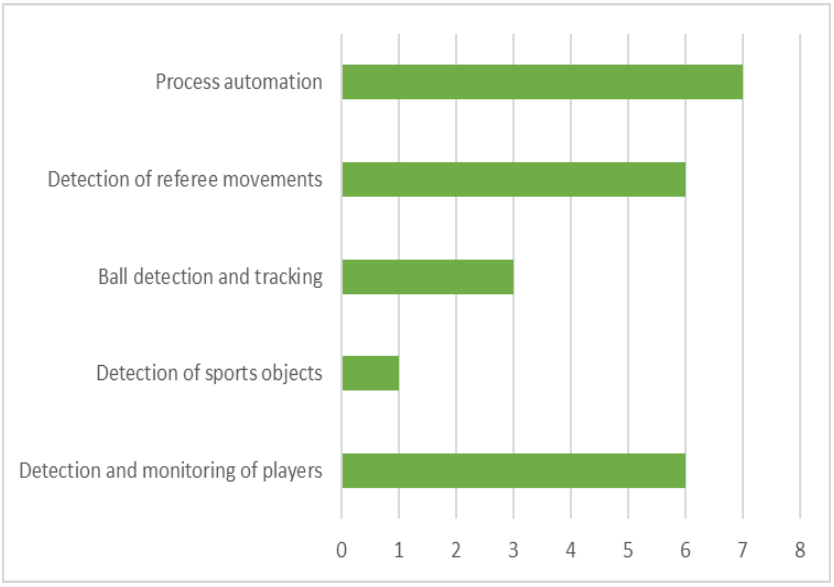

Figure 4. Solution Approaches for the development of technological assistants

In the selected articles, it was found that the types of problems can be evident in more than one sports discipline, as well as the objectives of their research. Thus, in soccer we have problems related to the detection and monitoring of players in incidents related to offside plays, caused by the pace of the game such as fouls due to divided balls.[15,24] Similarly, in tennis, we have problems detecting incidents that occur in plays with the ball and without the ball, as a result of not having an automated approach to be able to have precise judgments, thus, the objectives of these investigations arise, being able to find a technological solution focused on the detection and tracking of players and balls.[16,17,26] Likewise, we found that, in cricket, figure skating and wushu, similar problems are evident, such as having an obsolete and tedious process for detecting sporting repercussions in games of these sports, as well as for modifying the score of game markers and for detection of movements of players as referees for the issuance of a precise judgment, this being the origin of the reason for their studies, which seek to detect the movements of sports objects and referees for the detection of game moments such as automating processes to updating game scores.[6,8,10,11,12,18,21,22,23,25] Likewise, in other sports such as basketball, hockey, fencing, handball, race-walking, skateboarding, we also find problems with presence in more than one sporting discipline, which lie in having a traditional approach for detecting sports incidents.[7,9,11,13,14,19,20] All

Table 7. Solution approaches by scientific publication and sport

		Objectives				
Authors	**Sports**	**Detection and monitoring of players**	**Detection of sports objects**	**Ball detection and tracking**	**Detection of referee movements**	**Process automation**
Matsuyama et al.[6]	Figure skating					✓
Suzuki et al.[7]	Race Walking	✓				
Mili et al.[8]	Cricket		✓			
Jiang et al.[9]	Hockey	✓				
Nandyal et al.[10]	Cricket				✓	
Lu et al.[11]	Wu-shu					✓
Nandyal et al.[12]	Cricket				✓	

Xu et al.[13]	Handball					✓
Pan et al.[14]	Basketball					✓
Panse et al.[15]	Soccer	✓				
Jiang et al.[16]	Tennis					✓
Voeikov et al.[17]	Tennis					✓
Iyer et al.[18]	Cricket				✓	
Sunal et al.[19]	Fencing	✓				
Abdullah et al.[20]	Skateboarding	✓				
Kowsher et al.[21]	Cricket				✓	
Ravi et al.[22]	Cricket				✓	
Khan et al.[23]	Cricket			✓		
Kamble et al.[24]	Soccer			✓		
Shahjalal et al.[25]	Cricket				✓	✓
Reno et al.[26]	Tennis	✓		✓		

In the research studies presented, a wide range of technological solutions capable of addressing the problems and objectives presented were proposed. Having proposals of various characteristics as well as various artificial intelligence approaches for its development, it is thus that we have the development of an algorithm focused on the detection and monitoring of the trajectory of the ball as the game progresses, based on Transfer learning using principles of Deep learning by Kamble et al. [24], the development of systems capable of detecting and classifying sports actions with respect to snick moments in cricket games as well as for the detection of referee movements, making use of Neural networks Inception V3(CNN), VGG19 networks, techniques related to an approach based on Deep learning and Machine Learning.[22,23] Likewise, there is a segmentation method for predicting and evaluating the quality of actions performed in a figure skating competition, using Deep Learning.[6] Thus, we can show that the most useful artificial intelligence approaches for the development of solutions focused on the detection and monitoring of players, sports objects, and the identification of referee movements make use of Deep Learning and Machine learning principles and techniques. Likewise, it was found that there is a greater presence in the use of Convulsion Neural Networks (CNN) and Artificial Neural Networks (ANN) in the development of technological solutions, this is because they are useful for solutions focused on image and video processing, thus allowing us to detect and follow sports agents and objects.

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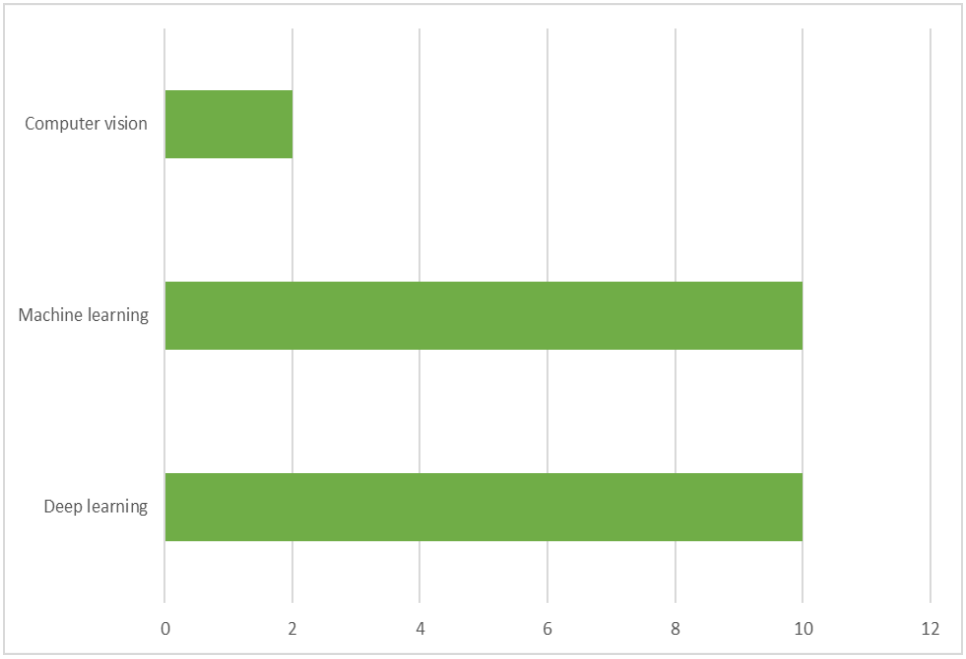

Figure 5. Artificial Intelligence approaches for the development of technological assistant

Table 8. Artificial Intelligence approaches for the development of technological assistants for sports

		AI approaches		
Authors	**Sports**	**Deep learning**	**Machine learning**	**Computer vision**
Matsuyama et al.[6]	Figure skating	✓		
Suzuki et al.[7]	Race Walking		✓	
Mili R et al.[8]	Cricket	✓		
Jiang Y et al.[9]	Hockey	✓		
Nandyal et al.[10]	Cricket		✓	
Lu et al.[11]	Wu-shu		✓	
Nandyal et al.[12]	Cricket		✓	
Xu et al.[13]	Handball	✓		
Pan et al.[14]	Basketball		✓	
Panse et al.[15]	Soccer	✓		
Jiang et al.[16]	Tennis	✓		
Voeikov et al.[17]	Tennis	✓		
Iyer et al.[18]	Cricket		✓	
Sunal et al.[19]	Fencing	✓		

Abdullah et al.[20]	Skateboarding		✓	
Kowsher et al.[21]	Cricket		✓	
Ravi et al.[22]	Cricket	✓		
Khan et al.[23]	Cricket		✓	
Kamble et al.[24]	Soccer			✓
Shahjalal et al.[25]	Cricket		✓	✓
Reno et al.[26]	Tennis	✓		

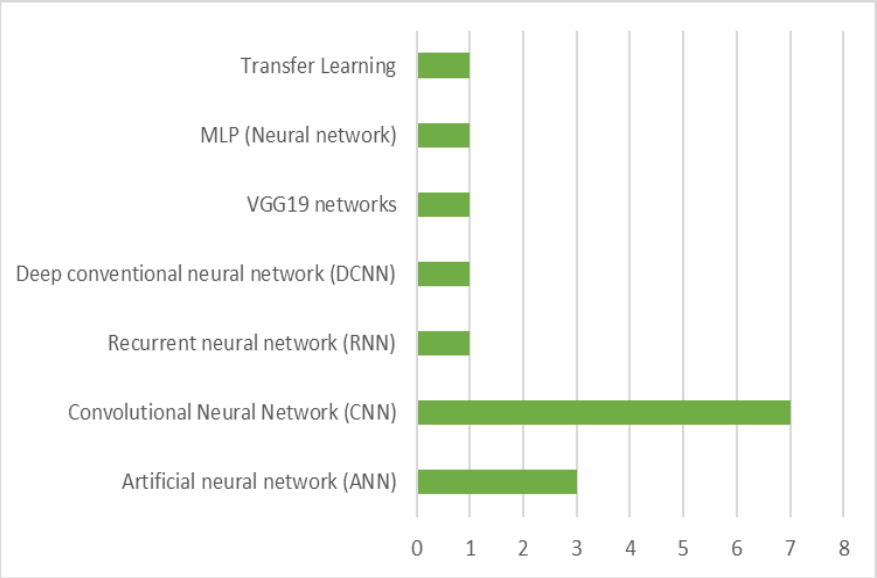

Figure 6. Artificial Intelligence Techniques

Addressing the structure by which the proposed proposals were designed and developed, studies were found, where the CNN architecture is used in sports disciplines such as football, cricket and tennis, for the automated identification and tracking of players and sports instruments used during gaming matches.[10,15,21,26] Likewise, we have other studies focused on making use of unusual architectures such as IRIS architecture, for the automation of scoring processes in figure skating by Matsuyama et al.[6], in turn, we have a technological solution, whose purpose lies in the detection of incidents in handball games, using a You Only Look Once Architecture (YOLOv3).[13] Going deeper into the models used for the composition of technological solutions, studies were found in which they make use of models related to the CNN architecture, this being the CNN model, for the development of algorithms, systems, methods and processing frameworks for the recognition and classification of sporting events that occur in sports such as football, cricket and hockey.[9,10,18,21,24] At the same time, we have studies that make use of the SVM model to develop solutions for the identification of movements of players and referees by Nandyal et al.[12] and Iyer et al.[18] such as those solutions that use a CNN model. Despite having two models with a similar approach, a greater preference was evident in the use of a CNN architecture and model. The reason is totally related to the objective, solution approach, AI approach and techniques used, since, turn out to be most useful for the development of solutions that aim to identify, track and classify sports objects (players, balls, sports instruments) on a playing field, to determine certain controversial plays to achieve precise judgments in matches. sports in different disciplines.

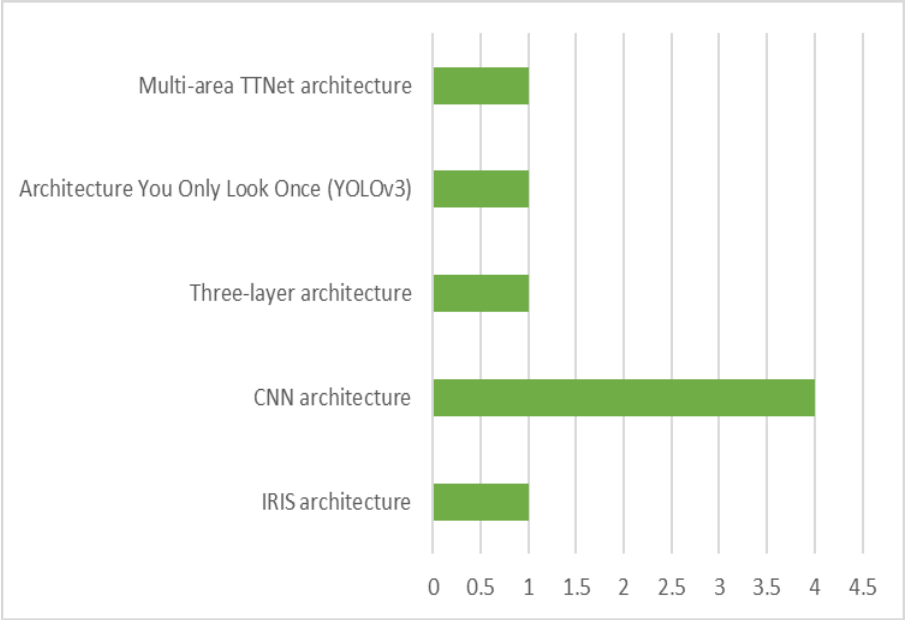

Figure 7. Artificial Intelligence Techniques

Figure 8. Types of AI models used for the development of technological assistants

Having analyzed the algorithms used in the research presented, it was found that there is a greater presence in the use of the support vector machine (SVM) algorithm, this is due to the fact that a large percentage of articles by Mili et al.[8], Iyer et al.[18], Kowsher et al.[21], Khan et al.[23] and Shahjalal et al.[25] aims to detect and/or identify movements of players and referees, thus allowing the use of this algorithm, as it is focused on the detection of events that occur through the processing of images and videos.

Likewise, the technological solutions, when tested in their test environment, demonstrated considerable effectiveness, thus meeting the expectations for which they were raised, having among the most encouraging results, a solution focused on the development of a real-time image processing framework. based on real network (CNN-RTIPF) to classify the movements made by hockey players, which managed to achieve an accuracy of 98,7 % by Jiang et al.[9], as well as a solution based on a method of identification and detection of referee movements, on the cricket field.[12]

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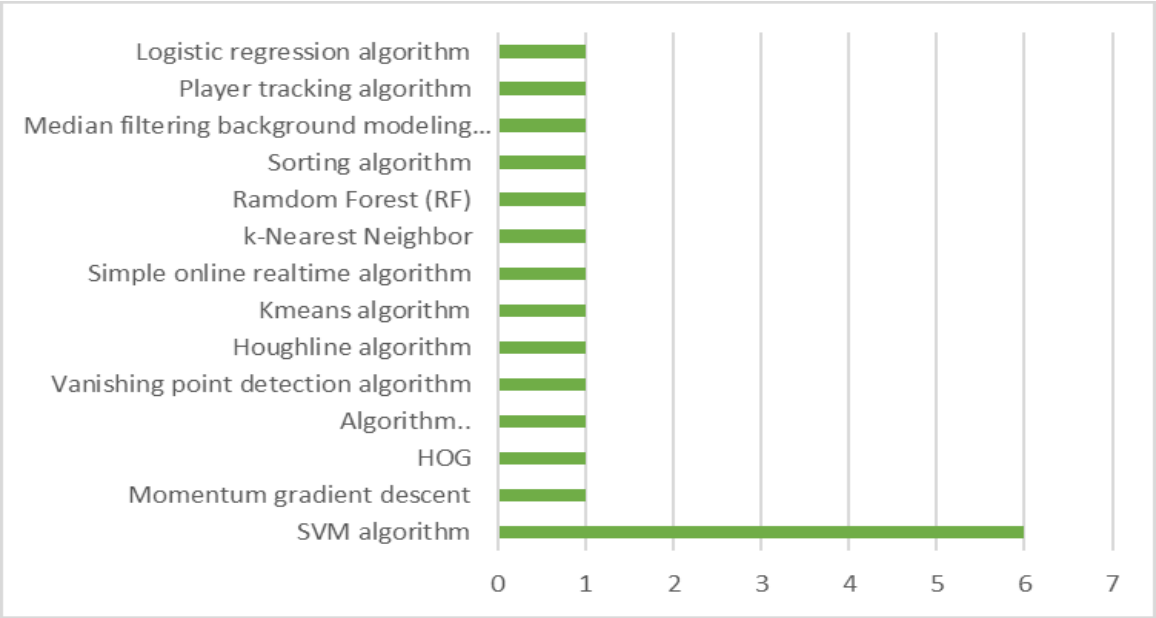

Figure 9. Algorithms used for the development of technological assistants

Table 9. Percentage of precision per Technological Assistant proposed by scientific publication

Authors	Precision
Matsuyama et al. [6]	X
Suzuki et al. [7]	90 %
Mili R et al. [8]	87 %
Jiang Y et al. (9)	X
Nandyal et al. [10]	98,20 %
Lu et al. [11]	X
Nandyal et al. [12]	97,95 %
Xu et al. [13]	91,30 %
Pan et al. [14]	95,78 %
Panse et al. [15]	85 %
Jiang et al.[16]	99,9 %
Voeikov et al. [17]	97,0 %
Iyer et al. [18]	88,89 %
Sunal et al. [19]	83,0 %
Abdullah et al. [20]	85 %
Kowsher et al. [21]	94 %
Ravi et al. [22]	88,78 %
Khan et al. [23]	85,7 %
Kamble et al. [24]	87,45 %
Shahjalal et al. [25]	88,13 %
Reno et al. [26]	98,77 %

Finally, we have the series of limitations presented when operating these solutions, where it was found that the problem with the greatest recurrence lay in the incorrect identification of sports objects in sports such as cricket, football, basketball, hockey, skateboarding and handball, sometimes, product of the dynamism of sporting events.

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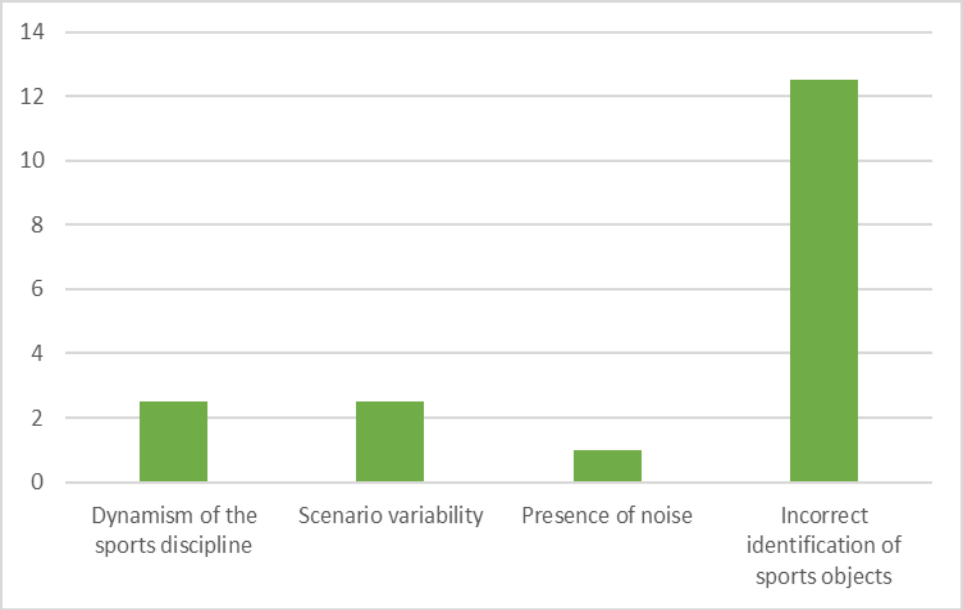

Figure 10. Limitations presented in operations of technological solutions

Table 10. Limitations presented in the execution of technological solutions for sports and scientific publications

Authors	Sports	Limitations			
		Dynamism of the sports discipline	Scenario variability	Presence of noise	Incorrect identification of sports objects
Matsuyama et al.[6]	Figure skating				✓
Suzuki et al.[7]	Race Walking				✓
Mili et al.[8]	Cricket	✓			
Jiang et al.[9]	Hockey				✓
Nandyal et al.[10]	Cricket				✓
Lu et al.[11]	Wu-shu	✓			
Nandyal et al.[12]	Cricket				
Xu et al.[13]	Handball				✓
Pan et al.[14]	Basketball				✓
Panse et al.[15]	Soccer				✓
Jiang et al.[16]	Tennis				✓
Voeikov et al.[17]	Tennis		✓		
Iyer et al.[18]	Cricket		✓		
Sunal et al.[19]	Fencing				✓

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Abdullah et al.[20]	Skateboarding				✓
Kowsher et al.[21]	Cricket				✓
Ravi et al.[22]	Cricket				✓
Khan et al.[23]	Cricket			✓	
Kamble et al.[24]	Soccer		✓		
Shahjalal et al.[25]	Cricket	✓			
Reno et al.[26]	Tennis				✓

DISCUSSION

In the review study presented, it was confirmed through the analysis of results, a greater predominance and/or interest in the research and development of technological solutions in the field of Cricket, in comparison to sports with greater relevance such as soccer, basketball and /or tennis. This is due to important factors described in these articles, first, we have that cricket turns out to be one of the emblematic sports in European and Asian countries, where there is a large monetary acquisition, which allows the promotion of projects. for research and development of technologies. Secondly, sport has been one of the founders in the implementation of technological solutions for its intervention in cricket games, thus generating optimal conditions for the application of technological items. In addition, it is one of the sports in which the premise of its collaborators is to seek to obtain precise decisions in the shortest possible time, to achieve a fair game. Finally, due to the conditions of the game, which are a large field, which makes it difficult to perceive some incidents.[8,10,12,21,22,23,25] Likewise, with respect to the problems and objectives of the proposed solutions, we can infer from the evidence of the results shown, that the premise of the technological assistants lies mainly in the detection and monitoring of sports objects as well as in the identification and classification of sports incidents, with cases in articles by Nandyal et al.[10], Iyer et al.[18], and Ravi et al.[22], in which systems capable of identifying and classifying the actions that occurred are used to be able to issue precise results, in order to have game games fair, in turn, this being the primary principle of the development of research articles. Likewise, the effectiveness in the operation of the technological solutions in their respective environments is evident, where promising results greater than 90 % were obtained Nandyal et al.[10], Jiang et al.[12] and Reno et al.[26] which led to the implementation of the proposals. At the same time, having verified the considerable level of precision of the proposed solutions and analyzed their composition, the effectiveness of the SVM and CNN models was evident, to perform functions related to the detection, monitoring and classification of sports objects in variable sports with regarding their scenarios and interactions between game participants.

CONCLUSIONS

In conclusion, technological solutions of various characteristics were found, ranging from the proposal of methods capable of detecting referee movements in cricket to algorithms capable of determining whether an offside action occurred in a soccer match. Thus, it was found that one of the main problems in the research landscape lies in being able to identify the participants in a sporting event, together with the associated instruments they use to perform in sport, all of this, to be able to identify incidents that occurred such as LEG'BY, FOUR, WIDE events, offsides, game infractions. To achieve this, have sporting events with precise and quick decisions, thus allowing for game games with a greater effective playing time and without controversial plays. Likewise, a sense of innovation and continuous improvement was seen in the field of cricket in the research and development of technological solutions. Addressing the technical aspects, the architectures, models and algorithms most used by the studies reviewed were based on Machine Learning and Deep Learning techniques, obtaining results with a level of precision in the range of 85 % to 99 % when tested in their respective test environments. Thus, having analyzed the percentage of precision of the solutions, it is recommended that for the development of technological assistants, whose purpose is the detection and monitoring of sports objects, these being the participants of the game, ball, game instruments, to the identification of sports incidents (offside plays, misplays, snicks), the use of architectures, models and algorithms related to Convolutional Neural Networks (CNN) and Support vector machine (SVM), since they present an approach which allows the identification of objects in spaces of variable dimensions and the monitoring of their trajectory, in addition to

being able to be trained to improve their performance, thus producing solutions with a continuous improvement nature.

REFERENCES

1. Spitz J, Wagemans J, Memmert D, Williams AM, Helsen WF. Video assistant referees (VAR): The impact of technology on decision making in association football referees. J Sports Sci [Internet]. 2021 Jan 17; 39(2):147–53. Available from: https://www.tandfonline.com/doi/abs/10.1080/02640414.2020.1809163

2. Kubayi A, Larkin P, Toriola A. The impact of video assistant referee (VAR) on match performance variables at men's FIFA World Cup tournaments. In: Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology [Internet]. London - England: SAGE Publications; 2021. p.187–91. Available from: https://journals.sagepub.com/doi/abs/10.1177/1754337121997581

3. Tamir I, Bar-eli M. The Moral Gatekeeper: Soccer and Technology, the Case of Video Assistant Referee (VAR). Front Psychol [Internet]. 2021 Jan 12 [cited 2023 Nov 9];11(613469):1–7. Available from: https://pubmed.ncbi.nlm.nih.gov/33510692/

4. Gutiérrez VF. La estructura organizacional del Gobierno Regional de Moquegua y su eficiencia funcional. Sincretismo 2021;2

5. Xu P, Ji X, Li M, Lu W. Small data machine learning in materials science. NPJ Comput Mater [Internet]. 2023 Mar 25; 9(1):1–15. Available from: https://www.nature.com/articles/s41524-023-01000-z

6. Gonzalez-Argote J. Analyzing the Trends and Impact of Health Policy Research: A Bibliometric Study. Health Leadership and Quality of Life 2023;2:28-28. https://doi.org/10.56294/hl202328

7. Suzuki T, Takeda K, Fujii K. Automatic detection of faults in race walking from a smartphone camera: a comparison of an Olympic medalist and university athletes. ArXiv [Internet]. 2022 Aug 24; 1(2):1–16. Available from: https://arxiv.org/abs/2208.12646v1

8. Mili R, Das NR, Tandon A, Mokhtar S, Mukherjee I, Paul G. Pose Recognition in Cricket using Keypoints. In: 9th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering, UPCON 2022 [Internet]. Prayagraj - India: Institute of Electrical and Electronics Engineers Inc.; 2022. p. 1–5. Available from: https://ieeexplore.ieee.org/document/9986481/authors#authors

9. Gonzalez-Argote J. Patterns in Leadership and Management Research: A Bibliometric Review. Health Leadership and Quality of Life 2022;1:10-10. https://doi.org/10.56294/hl202210

10. Nandyal S, Kattimani SL. Cricket Event Recognition and Classification from Umpire Action Gestures using Convolutional Neural Network. International Journal of Advanced Computer Science and Applications [Internet]. 2022 Autumn 30; 13(6):354–60. Available from: www.ijacsa.thesai.org

11. Lu J, Xie M. A Wushu Referee's Decision Support System Using Error Recognition Theory. Hindawi Mobile Information Systems [Internet]. 2022; 2022(7717254):1–8. Available from: https://dl.acm.org/doi/10.1155/2022/7717254

12. Coa YMF, Crisostomo NWF, Díaz-Barriga GE. Desarrollo económico sostenible bajo un régimen social sin preceptos éticos y morales: auditoría forense en contraposición de la corrupción. Revista Científica Empresarial Debe-Haber 2023;1:48-62

13. Xu J, Zhang Y, Ye A, Dai F. Real-time detection of game handball foul based on target detection and skeleton extraction. In: 2021 IEEE International Conference on Computer Science, Electronic Information Engineering and Intelligent Control Technology (CEI) [Internet]. Fuzhou - China: Institute of Electrical and Electronics Engineers Inc.; 2021. p. 41–6. Available from: https://ieeexplore.ieee.org/document/9574504

14. Pan TY, Chang CY, Tsai WL, Hu MC. Multisensor-Based 3D Gesture Recognition for a Decision-Making Training System. IEEE Sens J [Internet]. 2021 Jan 1; 21(1):706–16. Available from: https://ieeexplore.ieee.org/document/9153042

15. Panse N, Mahabaleshwarkar A. A Dataset & Methodology for Computer Vision based Offside Detection in Soccer. In: MMSports 2020 - Proceedings of the 3rd International Workshop on Multimedia Content Analysis in Sports [Internet]. Seattle - USA : Association for Computing Machinery, Inc; 2020. p.19–26. Available from: https://dl.acm.org/doi/10.1145/3422844.3423055

16. Castillo-Gonzalez W. Charting the Field of Human Factors and Ergonomics: A Bibliometric Exploration. Health Leadership and Quality of Life 2022;1:6-6. https://doi.org/10.56294/hl20226

17. Voeikov R, Falaleev N, Baikulov R. TTNet: Real-time temporal and spatial video analysis of table tennis. In: 2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW) [Internet]. Seattle - USA: IEEE Computer Society; 2020. p. 3866–74. Available from: https://ieeexplore.ieee.org/document/9150877

18. Iyer GN, Vignesh B, Sohan B, Dharmesh R, Raman V. Automated Third Umpire Decision Making in Cricket Using Machine Learning Techniques. In: 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS) [Internet]. Madurai - India: Institute of Electrical and Electronics Engineers Inc.; 2020. p.1216–21. Available from: https://ieeexplore.ieee.org/document/9121078

19. Auza-Santiváñez JC, Díaz JAC, Cruz OAV, Robles-Nina SM, Escalante CS, Huanca BA. mHealth in health systems: barriers to implementation. Health Leadership and Quality of Life 2022;1:7-7. https://doi.org/10.56294/hl20227

20. Abdullah MA, Ibrahim MAR, Shapiee MNA Bin, Mohd Razman MA, Musa RM, Abdul Majeed APP. The classification of skateboarding trick manoeuvres through the integration of IMU and machine learning. In: Lecture Notes in Mechanical Engineering [Internet]. Singapore - Singapore: Springer Science and Business Media Deutschland GmbH; 2020. p.67–74. Available from: https://link.springer.com/chapter/10.1007/978-981-13-9539-0_7

21. Kowsher M, Alam MA, Uddin MJ, Ahmed F, Ullah MW, Islam MR. Detecting Third Umpire Decisions Automated Scoring System of Cricket. In: 2019 International Conference on Computer, Communication, Chemical, Materials and Electronic Engineering (IC4ME2) [Internet]. Rajshahi - Bangladesh: Institute of Electrical and Electronics Engineers Inc.; 2019. Available from: https://ieeexplore.ieee.org/document/9036705

22. Murillo-Ticona TA, Berneso-Soto ML. Los Entornos Virtuales de Aprendizaje al rescate del servicio educativo. Sincretismo 2020;1

23. Khan A, Hussain SQ, Waleed M, Khan A, Khan U. An automated snick detection and classification scheme as a cricket decision review system. Turkish Journal of Electrical Engineering and Computer Sciences [Internet]. 2019 Jan 1; 27(6):4118–33. Available from: https://journals.tubitak.gov.tr/elektrik/vol27/iss6/7

24. Uman JMM, Arias LVC, Romero-Carazas R. Factores que dificultan la graduación: El caso de la carrera profesional de contabilidad en las universidades peruanas. Revista Científica Empresarial Debe-Haber 2023;1:58-74

25. Shahjalal MA, Ahmad Z, Rayan R, Alam L. An approach to automate the scorecard in cricket with computer vision and machine learning. In: 2017 3rd International Conference on Electrical Information and Communication Technology (EICT) [Internet]. Khulna - Bangladesh: Institute of Electrical and Electronics Engineers Inc.; 2018. p.1–6. Available from: https://ieeexplore.ieee.org/document/8275204

26. Reno V, Mosca N, Marani R, Nitti M, D'Orazio T, Stella E. Convolutional neural networks based ball detection in tennis games. In: IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops [Internet]. UT - USA: IEEE Computer Society; 2018. p.1839–45. Available from: https://ieeexplore.ieee.org/document/8575391

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The authors declare that there is no conflict of interest.

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