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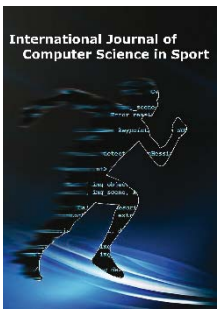

Test of a non-rectangular penalty area in the Euro 2016, Copa América 2016 and 2018 World Cup

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Abstract

A recent proposal for a new geometry of the penalty area for football (soccer) has been put to the test by analyzing games of the 2016 continental championships, the European and South American ones, and the 2018 FIFA World Cup which are by far the three most important nations tournaments in the sport. All matches after the first stage were analyzed and some instances were found in these critical or knockout matches in which the game and its fairness would have improved if the penalty area had been drawn according to mathematics or a measure of actual scoring chance.

KEYWORDS: PENALTY AREA, FOOTBALL, MATHEMATICS, EURO 2016, COPA AMÉRICA 2016, 2018 FIFA WORLD CUP, DIVING

Introduction

The FIFA World Cup, UEFA Euro, Copa América and UEFA Champions are watched by hundreds of millions of people around the world, and these very top football tournaments typically have plays around and inside the penalty area that arouse worldwide and important debates (Morales, 2016; Morris & Lewis 2010). The most debated type of controversy is related to a granted (or not granted) penalty kick, and these controversial plays are usually associated with a perception of simulation or diving by attackers (Morales, 2018). Perception is an important word herein; diving or simulation is human behavior or belongs to behavioral science (Morris & Lewis, 2010; David et al., 2011); that is, it is impossible in general to demonstrate that a player has deceived because a) solely he or she would know and b) different observers can have different judgements about a tackle play which involves two people. More generally, referee mistakes on the penalty area (related or not to dives) also spark such important controversies and the associated sense of unfairness.

Now, clear and blatant simulations that result in very unfair penalty kicks, or in general, the negative impact of referee errors close to goal, must be greatly reduced in football if a goal is to maintain or improve its worldwide popularity, marketability and quality (David et al., 2011; Morales, 2016).

After the 2014 FIFA World Cup, geometric change of the penalty area (PA) was first proposed, being the infamous dive by Robben against Mexico in the knockout stage, one of the unfair plays that inspired the germination of the innovative idea (Morales, 2016). The proposal is based on Mathematics and Human Behavior; that is, considering the fact that an attacker has an increased tendency to deceive when at a low-scoring-chance position, a measure of scoring chance was proposed: inversely and directly proportional to distance and angle towards goal, respectively (Morales, 2016). This theoretical proposal for measuring scoring potential according to position has been independently and lately backed by *scoring-chance density maps* which have resulted from different and several analyses of real data from professional football matches (Morales, 2018). This PA change will not only reduce the problem of simulation but also the more general one of unfair outcomes of referee mistakes in and around the PA, as argued by Morales (2016).

Nevertheless, that fully mathematical line or curve may be difficult to implement in the real world of football, the most popular sport that has thousands of tournaments at all its economic and generational levels. The reason is that the *tangent* and *square root* functions are involved, which are basic and simple in Analytical Geometry but very difficult to paint even in much resourceful tournaments as the World Cup or the Champions League. Consequently, a next step is to simplify geometrically that new PA line; this has been lately realized: the curve has been engineered or approximated by means of a couple of ready and easy *circular arcs* (Morales, 2018); thus, it is now easy and feasible to paint the new PA in practice or on the field. Moreover, the impracticality or problem of the mathematical perimeter starting at the posts has also been solved therein.

Now, the improved version does not change at all the original idea behind the proposition: the game and its fairness can be enhanced if the penalty area is drawn according to mathematics or a measure of actual scoring chance. Precisely, in this work we test the proposal in real and very top-level games. We have watched and analyzed all second stage and onwards matches in the 2016 UEFA European Championship (15 games), the Copa América 2016 (7 games) and the 2018 FIFA World Cup (15 games), and we present real situations in these definitive matches in which a) football and its fairness would have been improved, or not, if the non-rectangular PA had been painted and b) an attacker dives or simulates when at a low-scoring-chance position.

Note that *b* encounters are also *a* situations or plays where the game would have been enhanced. The tournaments were of course played with the current or rectangular PA; the new area was tested in post-tournament analysis involving computational overlapping of the proposed penalty contour.

Method

A novel boundary or periphery for the penalty box in association football has been just presented (Morales, 2018), it is shown in Fig. 1, where the current PA (dashed line) and the posts (points) are also depicted. This proposition will imply much fairer outcomes of different situations on the pitch close to the goal, where it is more critical (Morales, 2018). Moreover, it can be painted with the same current and international field tools and techniques; note that similar sports (e.g. futsal and field hockey) have for a long time been played with penalty areas made up of circular quarters and straight lines.

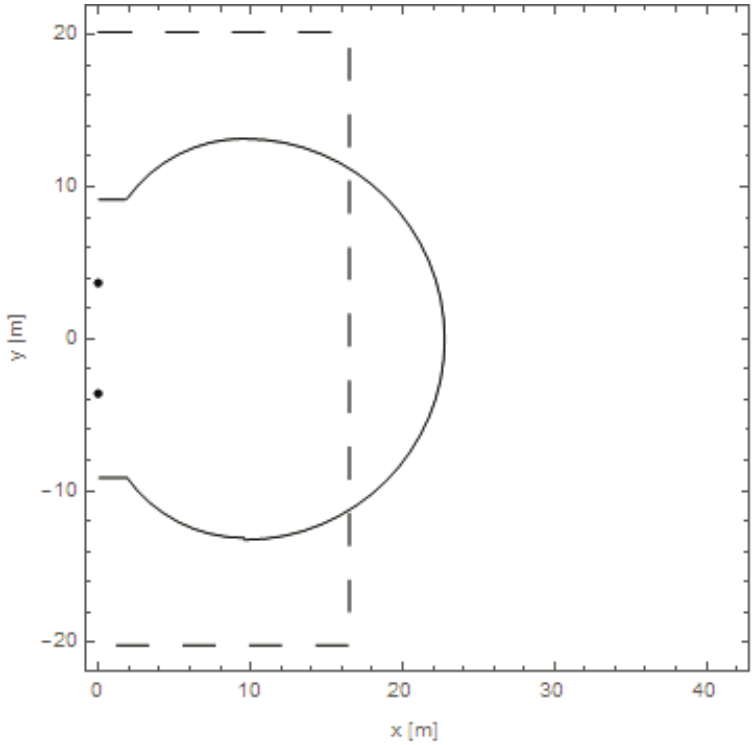

Fig. 1. Proposed (solid) and rectangular (dashed) penalty areas

Now, this new soccer penalty area (Fig. 1) is put to the test in the last European and South American nations championships, and the very last World Cup held in Russia. These two continental championships are the most important nations tournaments after the World Cup, and the FIFA World Cup is not only and by far the most prestigious nations tournament in football, but also the most widely followed and watched sporting event in the planet, above even the Olympic Games (Dobson & Goddard, 2011). All matches after the first stage were analyzed; it is considered that these knockout matches are the critical ones, because an unfair call or mistake by a referee in a first-stage game can decide that one, but national teams have two additional games in that stage to recover or balance that situation. Therefore, we analyzed *fifteen* 2016 UEFA European Championship matches, *seven* Copa América 2016 matches, and fifteen 2018 FIFA World Cup matches for a total of 37 games (CONMEBOL, 2016a; UEFA, 2106; FIFA 2018a).

The third-place match of the last two tournaments was not considered as these games were important in the past century, when the World Cup originated from the Olympic Games (which grant bronze medals), but these days those are considered truly *friendlies*; in fact, the Euro Championship does not have a *consolation* game since the early 80s.

We looked for pitch situations in those critical games in which a) the game and its fairness would have improved, or worsened, if the penalty area had been drawn according to the proposed measure of scoring chance, and b) an attacker simulates or dives when at a low scoring chance position. How to measure football fairness and its improvement in future work is a good question; one way can be to count the number of tweets that are *controversial discussions* (Rogers, 2016); Rogers (2016) divided world-cup tweets as: reaction to big goal, prediction of match outcome, controversial discussion and injury commentary.

Ten such situations are reported, and are explained in chronological order. The reported instances are presented as a picture where the central point (or couple of points) is a physical encounter or contact between attacker and defender; these are similar to Fig. 5 in the original paper (Morales, 2016) where the Robben-Márquez 2014 world cup encounter (Robben's infamous dive) was presented, whose unfair outcome indeed inspired the germination of the original idea. We name this instances with the last names of the attacker and defender, in that order. FIFA country codes are used for clarity after the last names, once; that is, it is not assumed that all readers know all football top players.

Results

As indicated, the game instances are reported in chronological order; it was fortunate that the first situation and explanation is the Griezmann-Duffy encounter (France-Ireland, 6-26-16) because it is the clearest example of the application of the new concept, and of its superiority over the rectangular and *old* PA. The first three situations are from the 2016 continental championships which were held in June-July in France and the USA.

Griezmann(FRA)-Duffy(IRL) encounter (France-Ireland 66'). This is a classic and fast counter attack play which allows the unique and advantageous final configuration in Fig. 2. The black circles will always indicate the attacking players while the white ones the defenders; the goalkeeper is indicated with an added cross, while the ball is with the attacking player being physically contacted by a defender (in the figures the contact is where two circles touch). Duffy tackles from behind when Griezmann is right in front of the goal, with only the goalkeeper in between who in addition is at a comfortable distance, for the attacker. Again, this was a unique or optimal opportunity for scoring, but the player is fouled from behind just before he enters the current PA or rectangle, which resulted in just a free kick for France and a red card for Duffy; that is a most unfair outcome for the attacking team. Now, this tackle occurs clearly inside the new PA, so that the result would be a much fairer penalty kick, a play that actually would be very similar to the kick that Griezmann was denied, if it is noticed that the distance between Griezmann and the goalkeeper is very close to 11 m. Even though Fig. 2 or a photograph of the play may be enough to make the case for the new PA, a video of the instance is also, or more, powerful (The Sydney Morning Herald, 2016, see 1:13-20 of video).

Regarding the other result, the red card, it can be argued that it is also unfair for the defending team although the tackle was from behind; other pundits of the game can consider that the red card is fair even though Duffy seems to be attempting to reach the ball (Getty Images, 2016) but makes illegal contact with Griezmann first. The important point is that the new PA also solves this debate because with the new rules (FIFA, 2017) which were designed to eliminate the *triple punishment*, the result for the defending team could have been a yellow card.

In other words, the new PA in this case would correct two simultaneous *unfair* outcomes, by allowing two more just results that complement each other: a penalty kick and a yellow card (in reality, Duffy was sent off and denied to play the next game, which is *double punishment*).

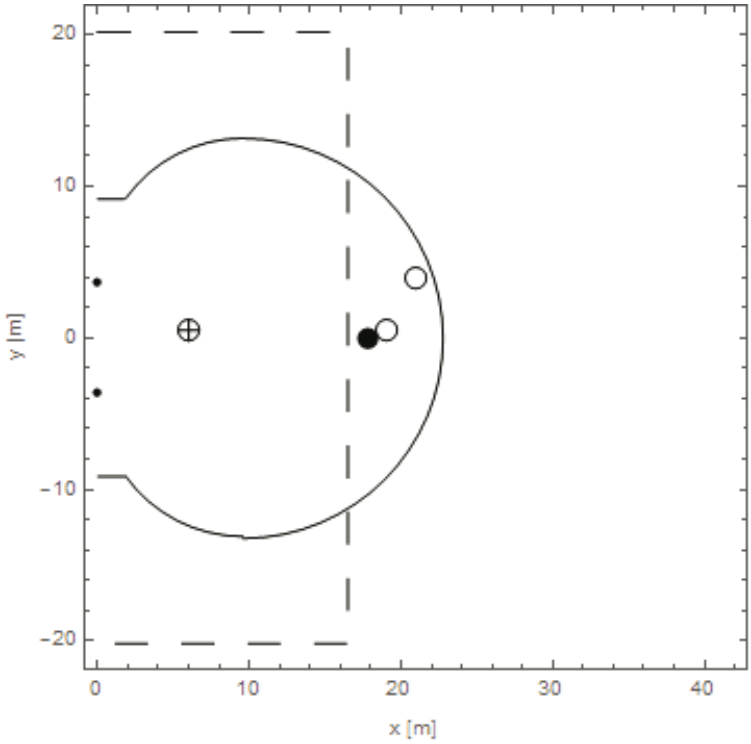

Fig. 2. Griezmann-Duffy encounter (France-Ireland 66')

Messi(ARG)-Fuenzalida(CHI) encounter (Argentina-Chile 40'). Now, this is another play that the analyst or we were looking for, a clear dive by an attacker when the angle and distance to goal are not favorable. The configuration of the play or when the simulation occurs is shown in Fig. 3: Messi dives at a low scoring chance point; in fact a) the dive happens outside de new penalty area which is an area where probability of scoring is higher, and b) also the referee (who did not have the advantage of t. v. replay) saw it and punished the attacker with a yellow card (CONMEBOL, 2016b); also note a densely defended area. It is an excellent and interesting example because one of the main goals of the proposed PA is to reduce simulation by players in the rectangular PA; as indicated in the Introduction, it has been shown that attackers have increased deceptive behavior when they are not on the central part of the current PA, or when on its lateral parts (David et al., 2011; Morales, 2016). Therefore, the game can be enhanced with the new PA because a) simulation situations like this can be reduced as the potential outcome for cheating players diminishes, and b) if still the referee is deceived by plays like this, at least the outcome would be just a free kick and not the executional penalty kick.

Pellè(ITA)-Ramos(ESP) encounter (Italy-Spain 32'). As in the first instance, this is also a clear foul in or around the penalty arc or *the D*. Likewise, it can be seen in Fig. 4 that the encounter or foul is inside the new PA; therefore, the result which was just a free kick could have been a more just penalty one, fairer because Pellè is also in front of the goal and the other two defenders are several meters away, although it is not as clear a chance as Griezmann's above.

The next seven instances are from the last FIFA World Cup which was held in Russia just last year (June-July 2018).

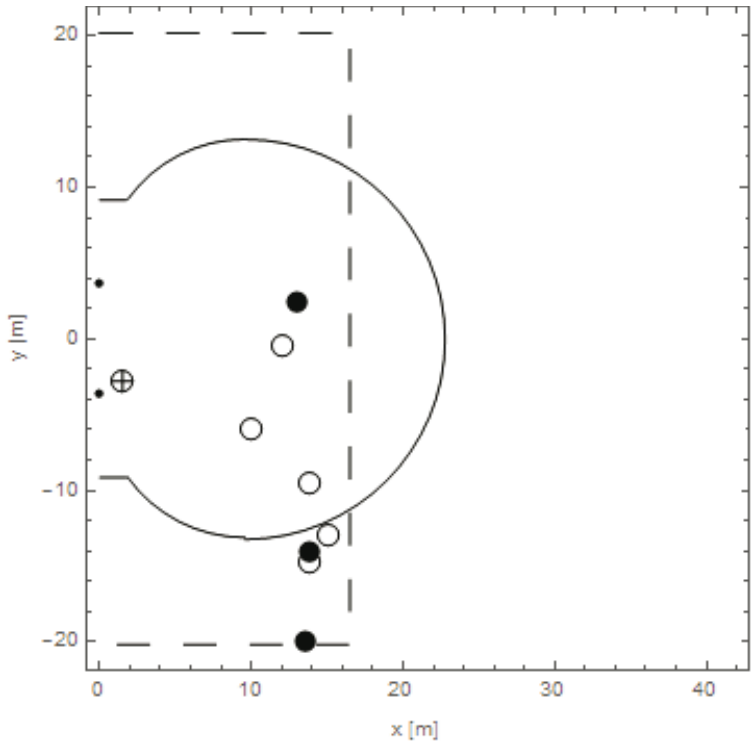

Fig. 3. Messi-Fuenzalida encounter or Messi dive (Argentina-Chile 40')

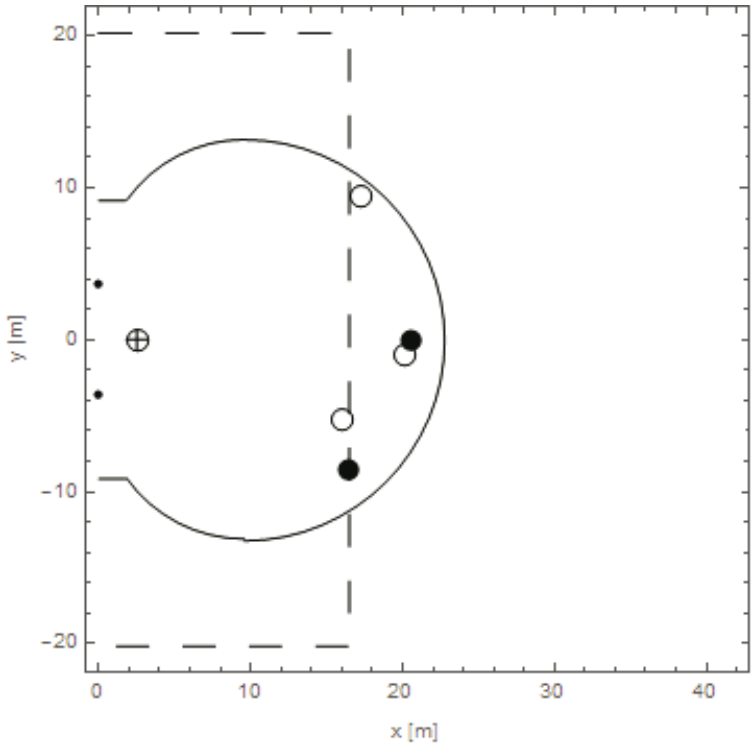

Fig. 4. Pellè-Ramos encounter (Italy-Spain 32')

Mbappé(FRA)-Rojo(ARG) encounter (France-Argentina 11'). This is another classic and fast counter attack play which results in the final configuration of Fig. 5; the actual chance of scoring is fair: not being the best configuration for a direct shot, the best chance is arguably a pass to the other attacker. Rojo finally pushes Mbappé inside the rectangular PA after some struggle between them.

Now, this foul occurs clearly outside the new PA, so that the result would have been a free kick. Although Mbappé's running direction is clearly not towards the goal but to dodge Rojo, it is up for discussion if this kick will be a fairer result of the play than the actual penalty kick, but it is the result with the new PA; furthermore, according to our mathematical model which does not consider a pass but solely direct shots, the chance of scoring was as low as approximately that of a position 30 m right in front of the goal (Morales, 2016); finally, note also the position of the goalkeeper, it seems that he also did not consider that the situation was dangerous, at least of a direct shot, but the most dangerous direct shot was granted to France: a penalty kick.

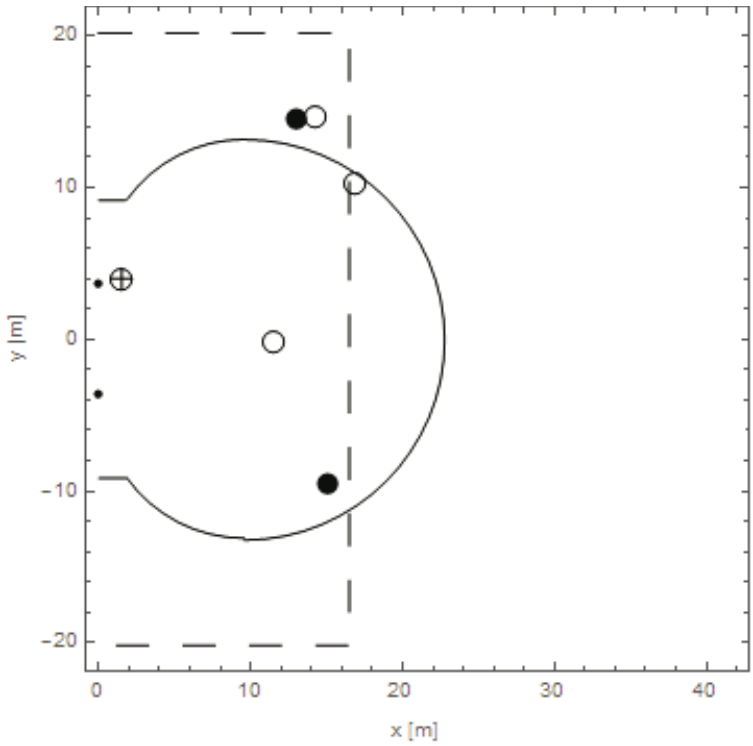

Fig. 5. Mbappé-Rojo encounter (France-Argentina 11')

Mbappé(FRA)-Tagliafico(ARG) encounter (France-Argentina 19'). This was also a fast counter attack play by the clearly superior team in that game, but the difference with the previous one is clear on Fig. 6 which is the final and an advantageous-for-shooting configuration. Tagliafico trips Mbappé while the attacker is almost in front of the goal, with only the goalkeeper in between who in addition is at a comfortable distance. This was an optimal opportunity for scoring, superior to the one above, but the player is fouled just before he enters the rectangle, which resulted in a mere free kick for France; again, that is a very unfair outcome for the attacking team. Now, this foul is committed clearly inside the new PA, so that the result would have been a fairer penalty kick, a play that actually is similar to the kick that Mbappé was denied; the distance between attacker and goalie is close to 9 m, and the distance of a penalty kick is 11 m.

Olsson(SWE)-Lang(SUI) encounter (Sweden-Switzerland 90'+3). This is a similar play to the previous one, but the final configuration is even more advantageous for a shot and actually, it is unique (Fig. 7), as in the very first example herein. Lang pushes from behind when Olsson is right in front of the goal with solely the goalie in between, who additionally is at a very comfortable distance.

We emphasize that it was a unique and optimal opportunity for scoring, but the player is tackled from behind just before he enters the rectangular PA, which resulted in just a free kick for Sweden and a red card for Lang; once again, that is a most unfair outcome for the offensive team. This foul also and clearly occurs inside the new PA; thus, the result would be a much fairer penalty kick, a kick that really would be very similar to the shot that Olsson was denied, if it is noticed that the distance between him and the goalkeeper is very close to *the* 11 m.

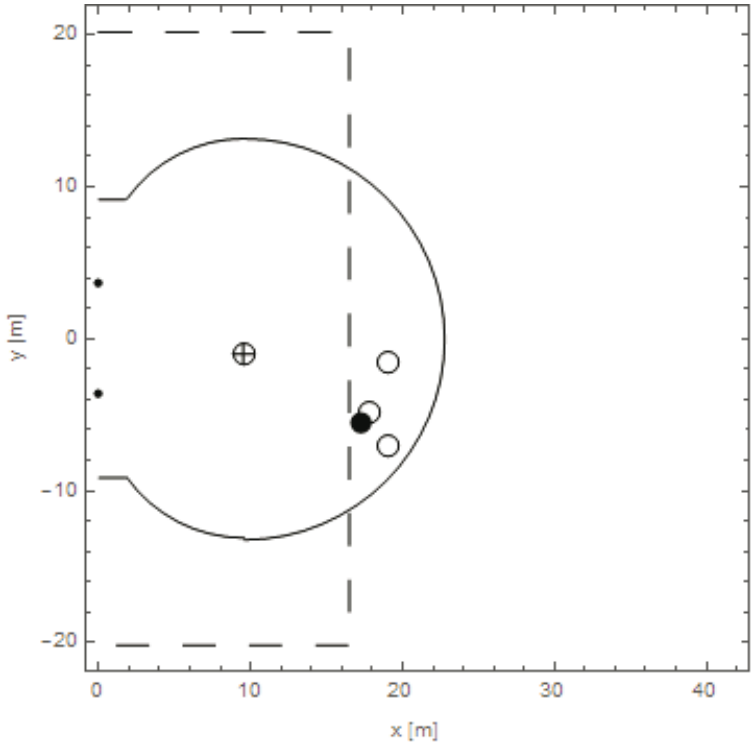

Fig. 6. Mbappé-Tagliafico encounter (France-Argentina 19')

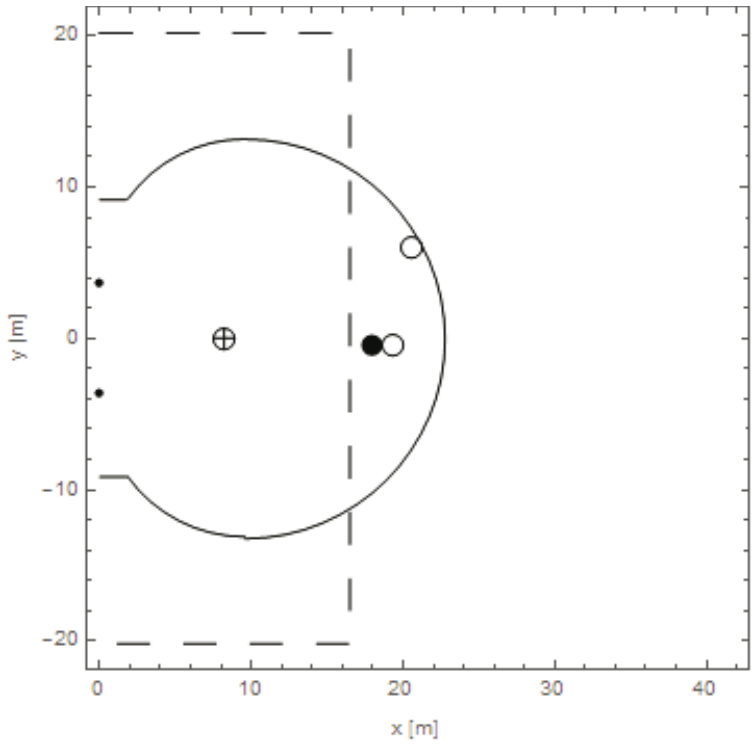

Fig. 7. Olsson-Lang encounter (Sweden-Switzerland 90'+3)

Although Fig. 7 may be sufficient to make the case for the new PA, at least in this play, there are two additional and interesting facts here. The first is related to the other result of the play or encounter: the red card. As in the first case or encounter, it can be argued in this case that it is also unfair for Switzerland even though the push was from behind; other football commentators may consider that the red card is fair although Lang pushes Olsson quite softly. The important point, again, is that the proposed PA also solves this debate because with the new rules implemented to eliminate the *triple punishment*, the result for the defending side would have been a yellow card. The discussion is similar to that of the Griezmann-Duffy encounter: the new PA would correct 2 simultaneous unfair outcomes by allowing 2 more fair results that complement each other (a penalty kick and a yellow card).

The other fact is related to the video assisted referee (VAR); the referee did not at first see that the foul was committed outside the rectangle and whistled a penalty kick; however, he went, or was advised to go, for the VAR. The fact is that it took the VAR system and the referee more than 2 minutes to correct the mistake. At least in this case or play, the new PA would have saved 2 minutes to a quarter billion live viewers; average live audience for a round-of-16 match was exactly 246 million (FIFA, 2018b). In this case we also refer to the respective and powerful footage of the play and consequences (Youtube, 2018)

Maguire(ENG)-Sánchez(COL) encounter (Colombia-England 63'). This is an additional instance that we or the analyst was expecting: a clear dive by an attacking player when the distance and angle to goal are not advatageous. The configuration when the diving occurs is shown in Fig. 8: Maguire simulates at a low scoring chance position; as a matter of fact a) the dive happens outside the new PA which is an area where chance of scoring is higher, b) the referee did not see a foul, and c) even English media considered it a clear dive and were calling for a yellow card for Maguire embelishment (The Guardian, 2018; Sky Sports, 2018); finally, note also a densely defended zone.

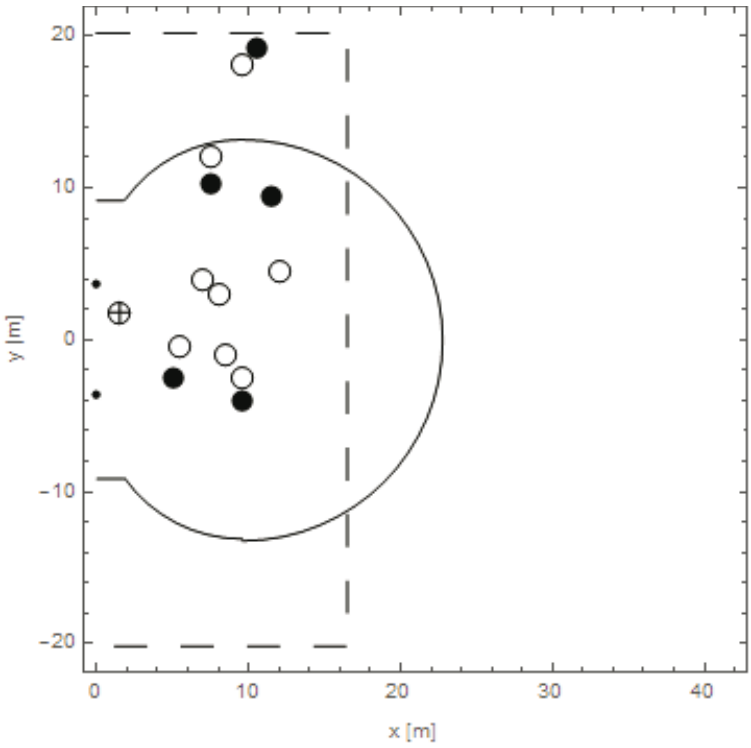

Fig. 8. Maguire-Sánchez encounter or Maguaire dive (Colombia-England 63')

Yet another interesting and excellent example because one of the main points of the new PA is to reduce diving by players close to but not in front of goal; it is stressed that attackers have increased deceptive behavior when they are not on the central part of the rectangular PA, or when they are on its lateral parts (David et al., 2011; Morales, 2016).

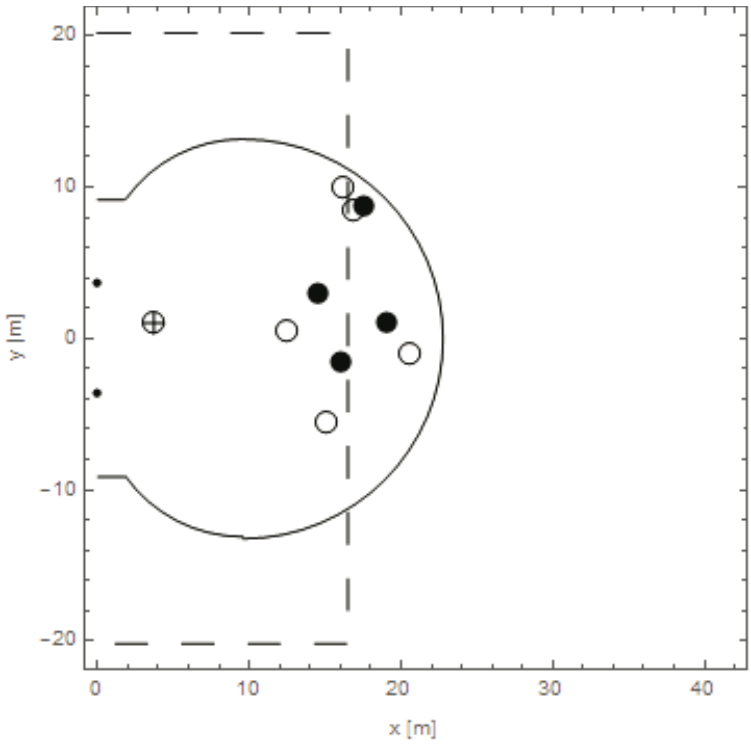

Fig. 9. Granqvist-Maguire encounter (Sweden-England 89')

Again, the sport can be improved with the proposal because diving can be diminished; moreover, if still the referee is deceived, at least the outcome would be just a free kick and not the *nuclear* penalty kick.

Granqvist(SWE)-Maguire(ENG) encounter (Sweden-England 89'). As in the Mbappé-Tagliafico encounter above, this is also a clear foul outside the old or rectangular PA. Likewise, it can be seen in Fig. 9 that the encounter is inside the new PA; therefore, the result which was just a free kick could have been a more *just* penalty one. Nevertheless, this can be considered a *negative result* or a real situation in which football and its fairness would not have been improved by the use of the new PA. This because a) this foul was a slight push, b) Granqvist was with his back to the goal, and c) there were 6 defenders around apart from the goalkeeper. Therefore, even though the foul position is similar to that of the second encounter above, in this case the enhancement of game fairness with the new PA is debatable.

Alli(ENG)-Modrić(CRO) encounter (Croatia-England 4'). The configuration and position of this play (Fig. 10) cannot be considered unique and optimal for goal, being an important difference with the Olsson-Lang encounter, the number of defenders; nonetheless, when Alli is strongly fouled from behind, he is still in front of and facing the goal, and has also the opportunity of passing the ball to the other attacker. Therefore, the result of a penalty kick with the new PA is considered a fairer result than the free kick that was simply granted. Nevertheless, it must be said that interestingly and in reality, the free kick resulted in a goal!

Sterling(ENG)-Vida(CRO) encounter (Croatia-England 63'). This is another simulation play by an attacker, or at least one medium or newspaper from the attacking country considered that embellishment or dive by Sterling was a real possibility (The Telegraph, 2018).

Again, Sterling's angle and distance –particularly the angle– to goal when he falls or dives was not favorable (Fig. 11); in fact, the play occurs outside the new PA, and the referee did not see any foul either.

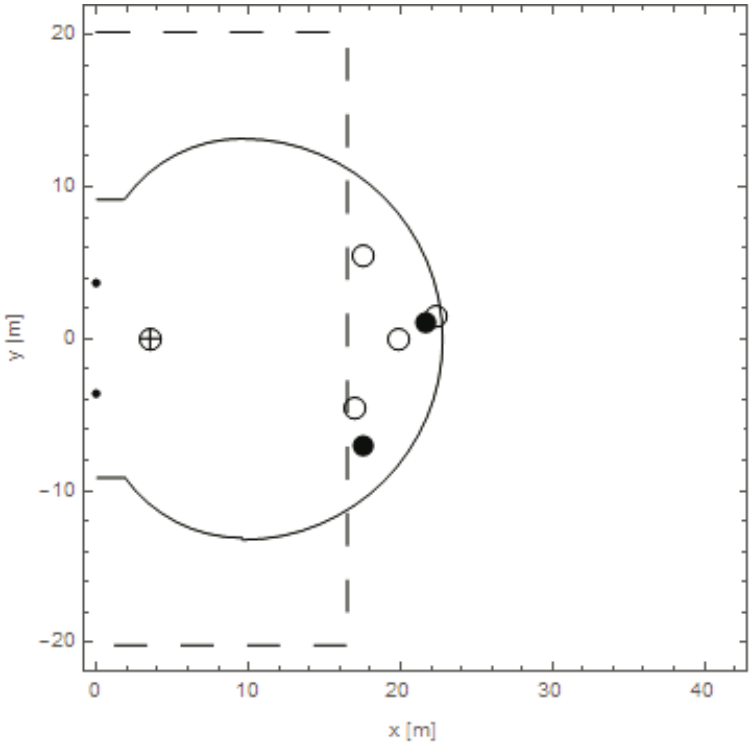

Fig. 10. Alli-Modrić encounter (Croatia-England 4')

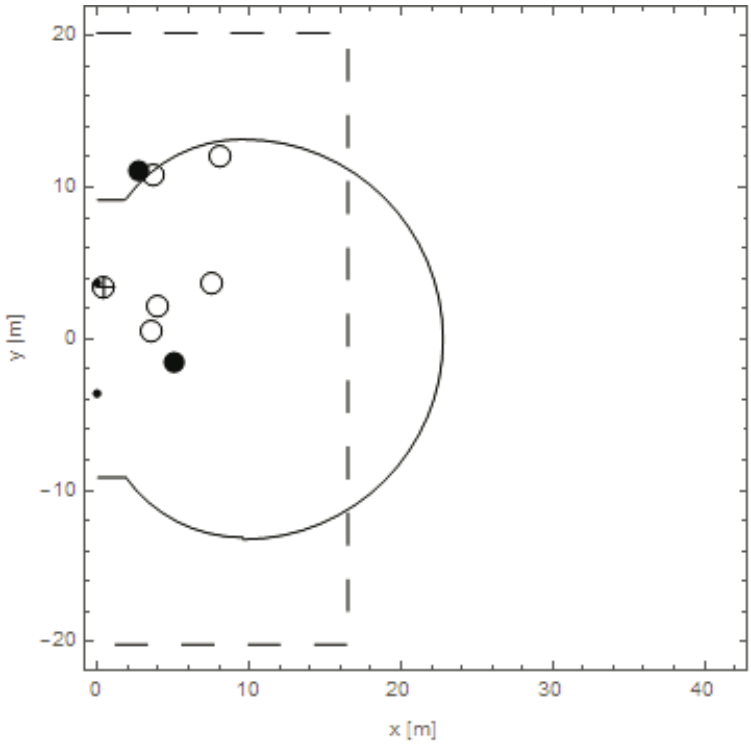

Fig. 11. Sterling-Vida encounter or Sterling dive (Croatia-England 63')

Discussion

Ten plays in the first-class games analyzed are related to our studies which in turn are related to enhancing the quality and maintaining the popularity and marketability of football. In five cases (Griezmann-Duffy, Pellè-Ramos, Mbappé-Tagliafico, Olsson-Lang and Alli-Modrić) the game and its fairness would definitely improve if the new PA were in play.

Moreover, in three plays, diving at a low-scoring-chance position was clear or noticed: Messi-Fuenzalida, Maguire-Sánchez and Sterling-Vida, being the first and second much clearer simulations than the third one; thus, these are examples of the fact that players are more prone to cheat when the potential outcome is more beneficial (David et al., 2011). These dives or encounters are considered also situations where the game would have been enhanced (Introduction); furthermore, more plays and situations similar to the 8 above –particularly dives outside the new PA– are expected if more games than 37 are analyzed.

In one situation (Mbappé-Rojo) it is not very clear that the new PA could have enhanced the game or resulted in a fairer outcome; finally, there is an instance (Granqvist-Maguire) in which the outcome with the proposal may not be fairer; in fact, this encounter may be considered –as discussed above– a *negative result* of this research.

As the 2016 and 2018 tournaments were played, of course, with the current PA, a limitation of the study or evaluation is that it cannot be assumed that player behaviour would have been the same if the new PA were implemented; nevertheless, at this point in time there is no other way to test the proposal in world-class professional matches, and the instances analyzed should be viewed simply as examples of these types of plays if the concern is that the result of the encounters would not have exactly been the same; in this regard, we are in talks with the athletics department of our university for painting the non-rectangular PA on our full size field (artificial turf) and use it during friendly matches.

Conclusion

A new non-rectangular penalty area has been presented by Morales (2016, 2018); the main idea is that this new PA can a) reduce the possibility of games being decided unfairly (or enhance the game) and b) diminish diving by players near the goal. Consequently, the proposal had to be tested in real and professional matches, and this is realized in this work.

Thirty seven high-level matches were analyzed and nine near-goal situations were detected in which football and its fairness would or could have been enhanced if the penalty area had been drawn as proposed; moreover, there were three dives, and these were on the lateral part of the rectangular PA, as expected because this is a zone where probability of scoring is low.

FIFA is looking for new, even radical, ideas for positive change in the beautiful game (Mirror, 2017), one coming from the scientific and engineering community should also be considered.

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