runs, and player positioning. Studying opposing teams' corner kicks exposes vulnerabilities, providing a strategic advantage in future encounters.

3 Data

The data is provided by SkillCorner and contains 9 matches. To be able to use the given data, a parsing section is essential. To serve this purpose, three data parsing classes are implemented to utilize the "matches.json" file and ("match_data.json", "structured_data") files for each match. For details, see section 8.1.

4 Methodologies

4.1 Corner Kick Identification and Preprocessing

In order to identify corner kick events from the tracking data provided by SkillCorner [1], the definition of the International Football Association Board [4] and the approach taken from the paper "Automatic event detection in football using tracking data" [5] is combined.

4.1.1 International Football Association Board

According to Football Association Board the following rules should apply:

- The ball must be placed in the corner area [4].
- The ball must be stationary and is kicked by a player of the attacking team [4].
- Opponents must remain at least 9.15 m (10 yds) from the corner arc until the ball is in play [4].

4.1.2 Automatic event detection in football using tracking data

Considering the procedure defined by International Football Association Board, the paper suggests that at least one player should be within ϵ_c of one of their active corner marks [5].

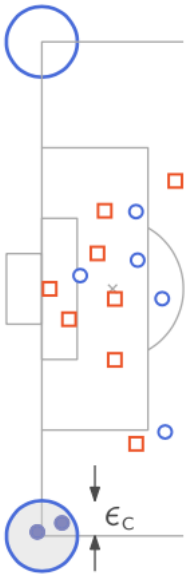


Figure 1: Corner Kick Identification [5] (The players participating in taking the corner kick are indicated by filled circles.)

4.1.3 Approach Taken

Considering that spatial locations of the ball and players are not consistently available i.e. missing in some of the frames and do not have a certain pattern, including the location of the ball during the detection of corner kick frames prevents identification of some of the corner kicks. Considering that the dataset contains limited amount of matches, it is crucial to not miss any corner kick intervals.

Therefore, initially, the position of the players of the team that will take the corner and the position of the opponent players are taken into account. The basic detection conditions are as follows:

- At least one player from attacking team should be within $\epsilon_c = 2$ of one of the active corner marks [5].
- Opponents must remain at least 9 meters from the corner arc until the ball is in play [4].

Taking into account that players took a few steps back before taking the corner and depending on the feet used (left/right), the corner takers are located in the circle with a center on a corner mark with radius $\epsilon_c = 2$ as in Corner Kick Identification figure (1).

After classifying some of the frames as corner kick events, it is essential to identify the misclassified routines (i.e. the detected frame interval does not indicate a corner kick routine) and split the corner kick events so that each of them can be further analyzed individually and prevents from analyzing the same routine more than once. For this purpose, the following preprocess methodology is applied:

- Given that sampling rate is 10 fps [1], a gap with duration 600 frames i.e. 1 minute is utilized to split the corner kick events.
- A corner kick event which is detected in less than 3 frames is considered as a noisy detection and discarded.

4.2 Analysis

In the analysis section, the aim is to provide the coach with beneficial insights regarding the opponent team. For this purpose, the distribution of players to different zones (inside the penalty area, outside the penalty area, inside the goal area), the roles of players in these zones, the probable defending tactics (man marking or zonal defending), and the positioning of the opponent's players are analyzed.

4.2.1 Distribution of players to different zones

At the end of the corner kick identification phase, the corner kicks are detected, and their frames are stored along with the team and match information. Using this data, the start and end frames for each corner kick routine are retrieved. The spatial locations of players from both teams are then obtained for the start and end frames. Given the pitch dimensions as shown in the figure (2), the number of players and their respective locations at the beginning and end frames of the corner kicks are detected. Finally, for each corner kick routine, and for each team, the number of players inside/outside the penalty area together with the number of players in goal area is obtained.

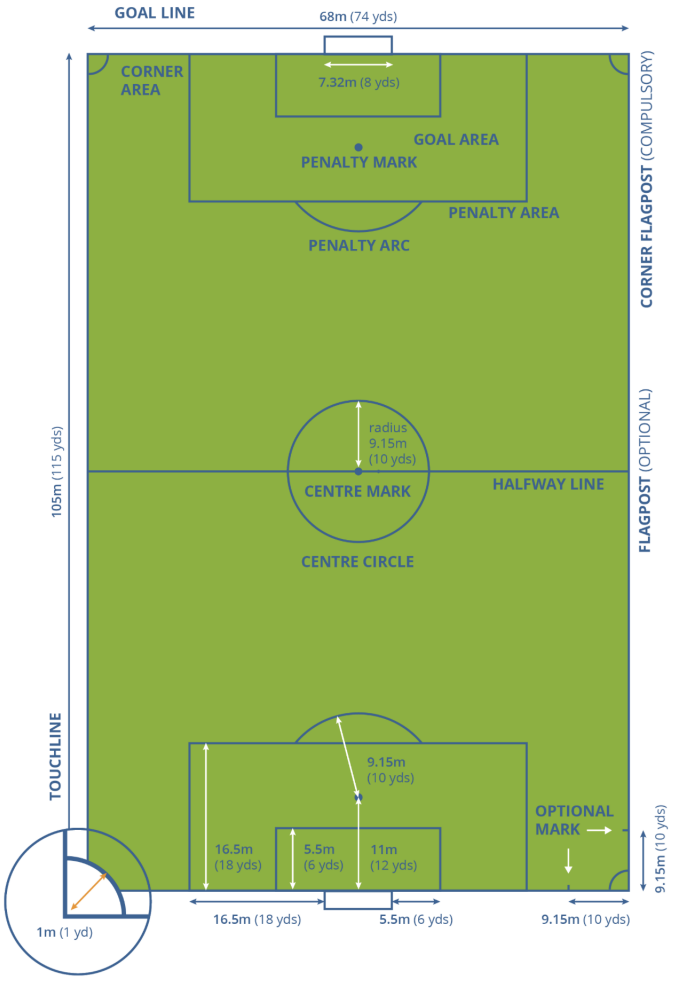


Figure 2: Pitch Dimensions [2]

4.2.2 Role of the players in different zones

By utilizing the output of the methodology in the "Distribution of players to different zones" section, the locations of the players can be determined for the detected corner kick events. By utilizing the "trackable object" values in both the match data and tracking data, the players' roles can be matched with their corresponding locations for a given frame. Similar to the methodology in the "Distribution of players to different zones" section, this approach assigns roles to the players for the start and end of each corner kick routine for each team.

4.2.3 Defending Tactics

Considering the availability of spatial locations for both teams' players in the corner kick routines, a detailed analysis of the end frames of each corner kick event can be conducted to uncover the defensive tactics employed by the opponent team. To achieve this objective, the distance between each defending team's player and each attacking team's player needs to be taken into consideration. For each defending team's player, the minimum observed distance to any attacking player should be calculated. Subsequently, by employing a heuristic distance threshold of distance $d = \{1, 1.5, 2\}$, the defending players with a minimum distance less than d to an attacking player are classified as man markers, while those with a minimum distance greater than d are classified as zonal defenders.

4.2.4 Positioning of Players

For each opponent team, the corner events are iterated and the opponent team's players spatial locations are fetched and processed such that all the corner kick events took place in a single corner arc. Each location is treated as a single data point. Afterward, for each opponent team, a k-means clustering model is trained with the number of clusters $k = \{5, 6, 7\}$. Then, data points and cluster centroids are visualized on a pitch by assigning a distinct color to each cluster. This visualization reveals the tactical positioning of the opponent team's players during corner kicks. The determination of the number of clusters necessary to understand a team's corner tactic does not need to be fixed. Therefore, it is beneficial to experiment with different numbers of clusters and observe the plots to identify the optimal representation.

5 Results

For the visuals of the corner kick events, the red dots represent the home team, the blue dots represent the away team and where available, the green dot represents the ball.

5.1 Corner Kick Identification

According to the methodology used in section 4.1, the corner kicks events are detected for the given matches in the dataset. Below, you can see the identified corner kicks for each match.

Inter vs Juventus

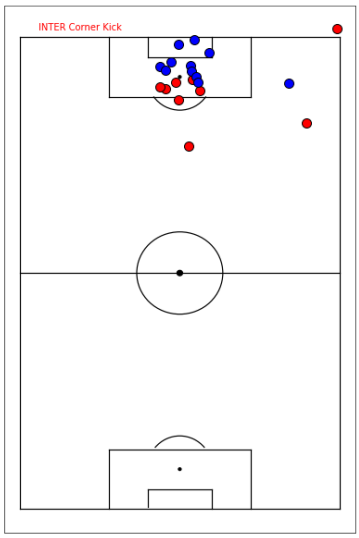


Figure 3: Inter Corner Kick

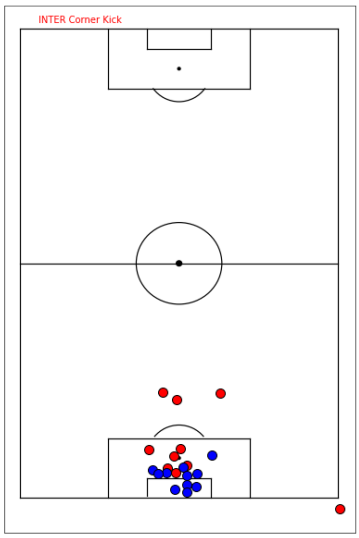


Figure 4: Inter Corner Kick

Figure 5: Identified Inter Corner Kicks in the Inter vs Juventus match

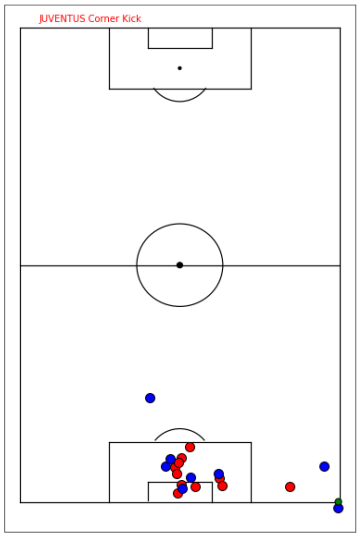


Figure 6: Juventus Corner Kick

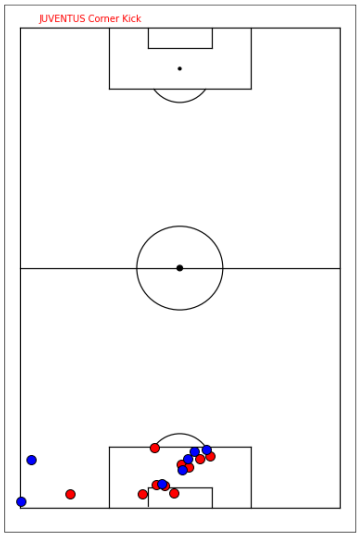


Figure 7: Juventus Corner Kick

Figure 8: Identified Juventus Corner Kicks in the Inter vs Juventus match

PSG vs Marseille

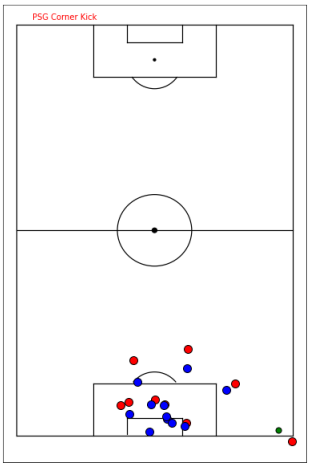


Figure 9: Identified PSG Corner Kicks in the PSG vs Marseille match

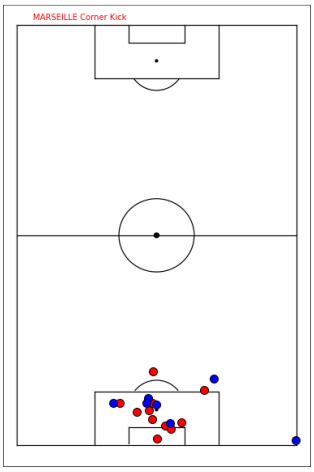


Figure 10: Marseille Corner Kick

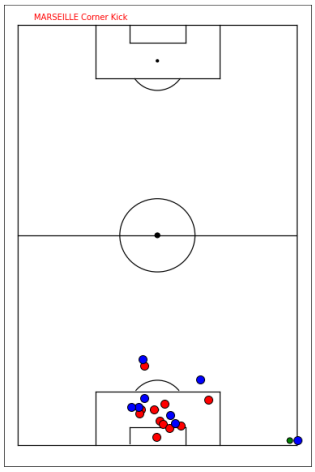


Figure 11: Marseille Corner Kick

Figure 12: Identified Marseille Corner Kicks in the PSG vs Marseille match

Bayern Munich vs Borussia Dortmund

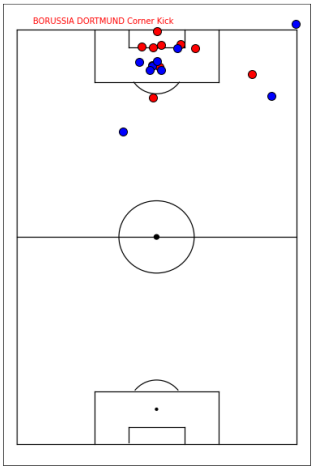


Figure 13: Borussia Dortmund Corner Kick

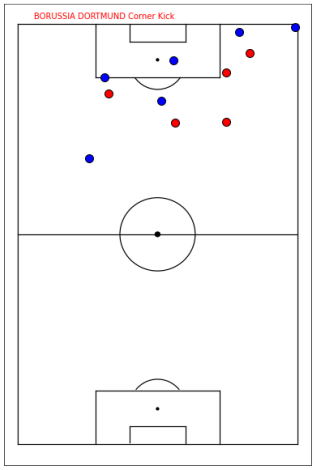


Figure 14: Borussia Dortmund Corner Kick

Figure 15: Identified Borussia Dortmund Corner Kicks in the Bayern Munich vs Borussia Dortmund match

Liverpool vs Manchester City

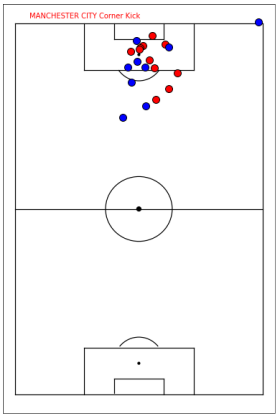


Figure 16: Manchester City Corner Kick

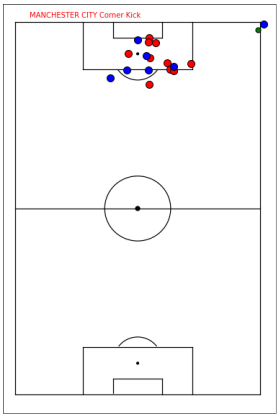


Figure 17: Manchester City Corner Kick

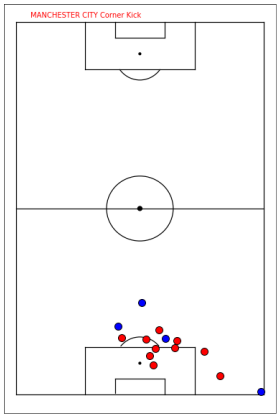
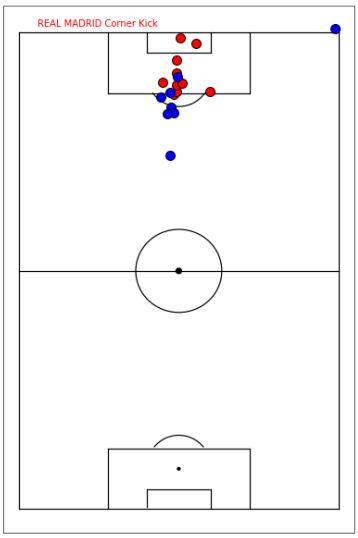


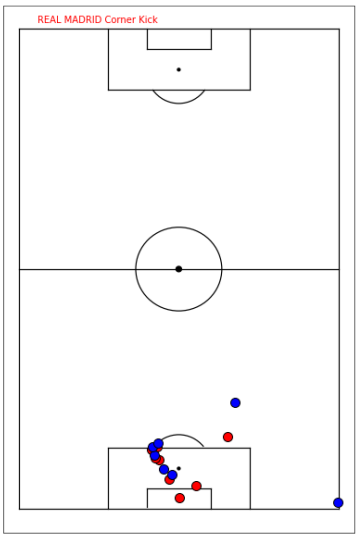
Figure 18: Manchester City Corner Kick

Figure 19: Identified Manchester City Corner Kicks in the Liverpool vs Manchester City match

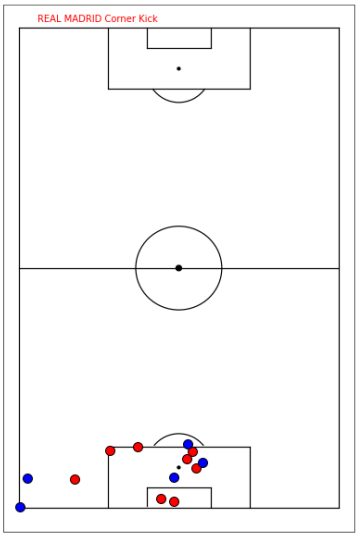
Barcelona vs Real Madrid



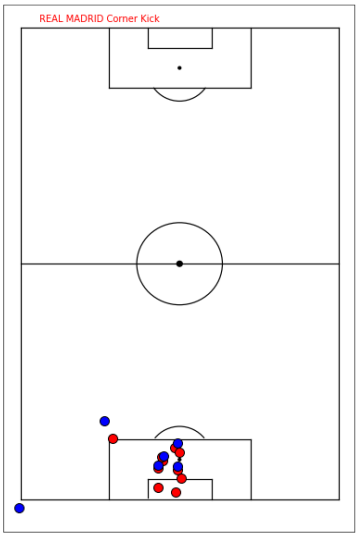
(a) Real Madrid Corner Kick



(b) Real Madrid Corner Kick



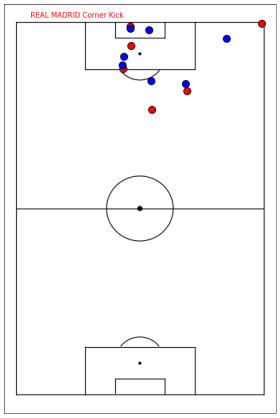
(c) Real Madrid Corner Kick



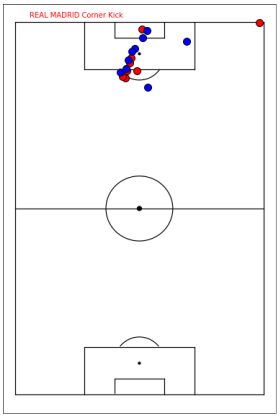
(d) Real Madrid Corner Kick

Figure 20: Identified Real Madrid Corner Kicks in the Barcelona vs Real Madrid match

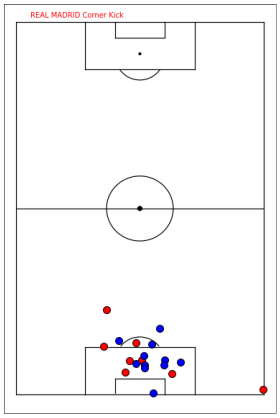
Real Madrid vs Barcelona



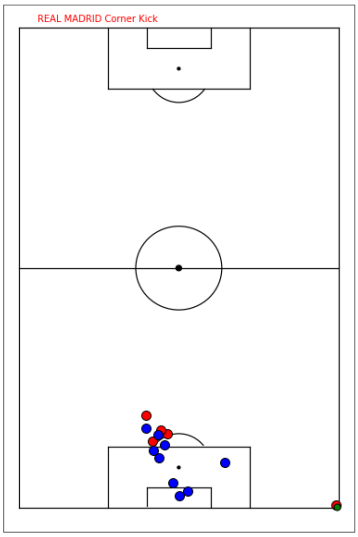
(a) Real Madrid Corner Kick



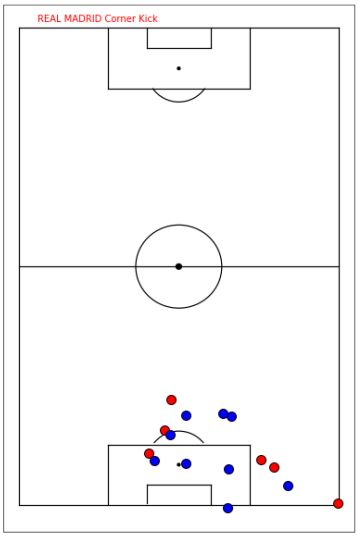
(b) Real Madrid Corner Kick



(c) Real Madrid Corner Kick



(d) Real Madrid Corner Kick



(e) Real Madrid Corner Kick

Figure 21: Identified Real Madrid Corner Kicks in the Real Madrid vs Barcelona match

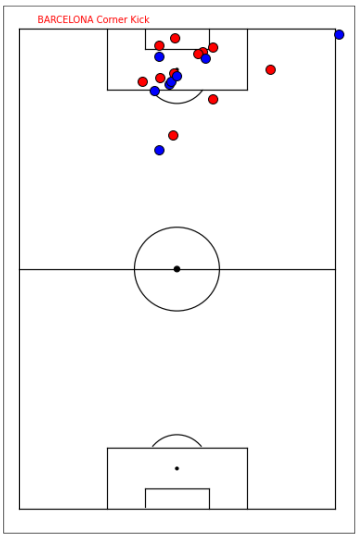


Figure 22: Barcelona Corner Kick

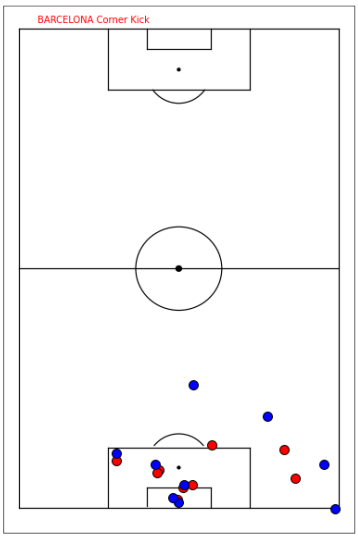
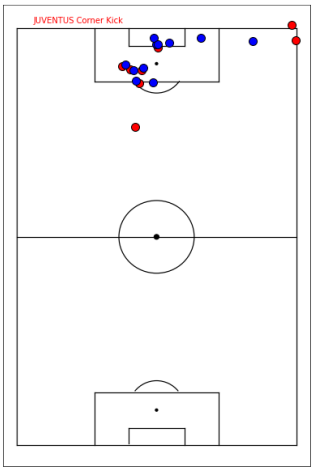


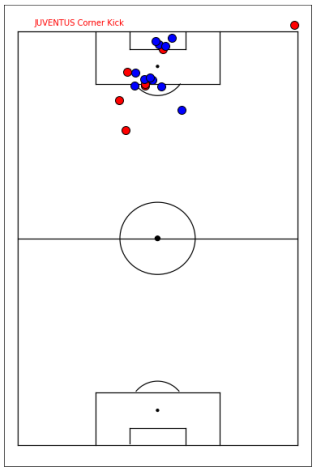
Figure 23: Barcelona Corner Kick

Figure 24: Identified Barcelona Corner Kicks in the Real Madrid vs Barcelona match

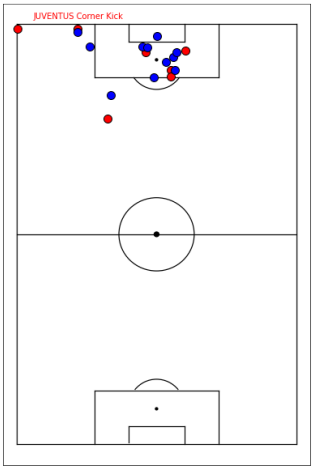
Juventus vs Inter



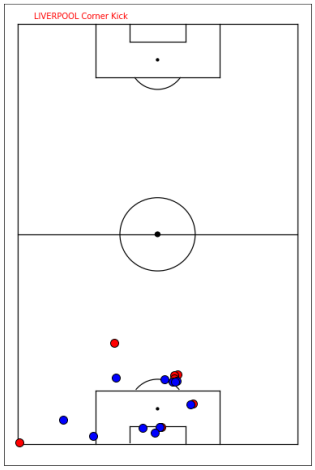
(a) Juventus Corner Kick



(b) Juventus Corner Kick



(c) Juventus Corner Kick



(d) Juventus Corner Kick

Figure 25: Identified Juventus Corner Kicks in the Juventus vs Inter match

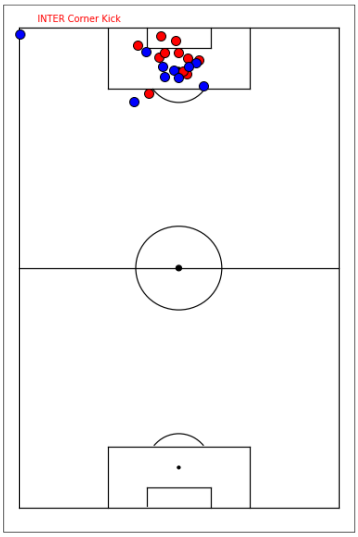


Figure 26: Inter Corner Kick

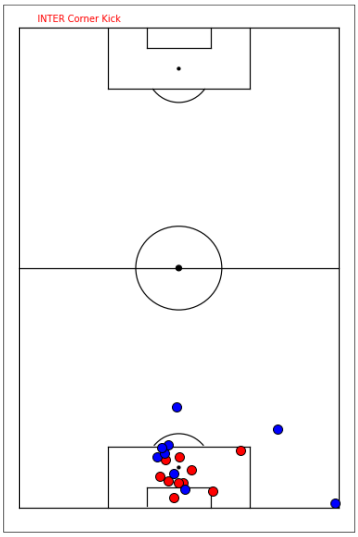


Figure 27: Inter Corner Kick

Figure 28: Identified Inter Corner Kicks in the Juventus vs Inter match

Manchester City vs Liverpool

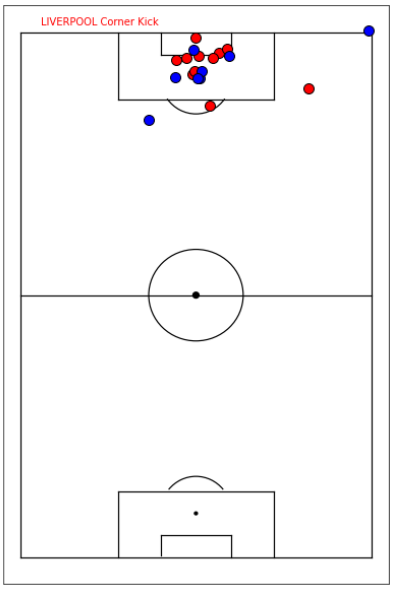


Figure 29: Identified Liverpool Corner Kicks in the Manchester City vs Liverpool match

5.2 Distribution of players to different zones

For each corner kick, distribution of the players to the different zones are obtained together with the roles of the players. For each corner kick, the distribution is analyzed for start and end frames. Please note that due to missing information at some of the frames, some of the players could not be matched with their roles. The following abbreviation applies: PA = Penalty Area, GA = Goal Area.

Inter vs Juventus

Inter Inside PA	Inter Inside GA	Inter Outside PA	Juventus Inside PA	Juventus Inside GA	Juventus Outside PA
5	0	4	10	3	1
'RCB','LF' 'RF','LCB'	-	'CM','RM' 'CB','LW'	'GK','RF','RCB','RWB','CM' 'AM','RM','LM','LCB'	'GK','RM','CM'	'LF'

Table 1: Inter vs Juventus Start of Corner Kick: Figure (3)

Inter Inside PA	Inter Inside GA	Inter Outside PA	Juventus Inside PA	Juventus Inside GA	Juventus Outside PA
6	0	3	10	3	1
'LF','LCB','RF' 'RW','CB'	-	'RM','LW'	'GK','RF','RCB','AM','LWB' 'RWB','RM','LM','CM','LCB'	'GK','LM','CM'	'LF'

Table 2: Inter vs Juventus End of Corner Kick: Figure (3)

- - - - - - - - - - - - - - - -

Inter Inside PA	Inter Inside GA	Inter Outside PA	Juventus Inside PA	Juventus Inside GA	Juventus Outside PA
3	1	7	7	1	2
'RM','RF','LM'	'RF'	'RW','LW','CM' 'RCB','LCB','CB'	'GK','LF','RF' 'LM','RWB'	'GK'	'RM','AM'

Table 3: Inter vs Juventus Start of Corner Kick: Figure (4)

Inter Inside PA	Inter Inside GA	Inter Outside PA	Juventus Inside PA	Juventus Inside GA	Juventus Outside PA
6	0	4	11	4	0
'LM', 'RF', 'RCB 'CB','LF'	-	'RW','CM' 'LW','RM	'LM','RCB','CM','RM' 'GK','RF','RWB','LF'	'CM','GK','RF'	-

Table 4: Inter vs Juventus End of Corner Kick: Figure (4)

- - - - - - - - - - - - - - - -

Inter Inside PA	Inter Inside GA	Inter Outside PA	Juventus Inside PA	Juventus Inside GA	Juventus Outside PA
10	3	1	5	1	3
'RW','RF','GK','LM	'RF','GK','CB'	'LW'	'LCB','CM','RF'	'CM'	'LF', 'AM'
'RCB','LCB','RM','CM','CB'				-	-

Table 5: Inter vs Juventus Start of Corner Kick: Figure (6)

Inter Inside PA	Inter Inside GA	Inter Outside PA	Juventus Inside PA	Juventus Inside GA	Juventus Outside PA
10	3	1	5	1	3
'RW','RF','GK','LM	'RF','GK','CB'	'LW'	'LCB','CM','RF'	'CM'	'LF', 'AM'
'RCB','LCB','RM','CM','CB'				-	-

Table 6: Inter vs Juventus End of Corner Kick: Figure (6)

- - - - - - - - - - - - - - - -

Inter Inside PA	Inter Inside GA	Inter Outside PA	Juventus Inside PA	Juventus Inside GA	Juventus Outside PA
8	1	2	4	0	3
'LF','CB','LW'	-	'LM','RM'	'RCB','RM'	-	'AM','LCB','CM'
'LCB','RF','CM','RW'					

Table 7: Inter vs Juventus Start of Corner Kick: Figure (7)

Inter Inside PA	Inter Inside GA	Inter Outside PA	Juventus Inside PA	Juventus Inside GA	Juventus Outside PA
9	3	2	4	0	3
'LF','CB','LW','GK'	'LW','GK','RF'	'LM','RM'	'RCB','RM'	-	'AM','LCB','CM'
'LCB','RF','CM','RW'					

Table 8: Inter vs Juventus End of Corner Kick: Figure (7)

PSG vs Marseille

PSG Inside PA	PSG Inside GA	PSG Outside PA	Marseille Inside PA	Marseille Inside GA	Marseille Outside PA
5	0	4	8	3	3
'CM','CF'	-	'RM','RW'	'LWB','GK','RW'	'LWB','GK','CM'	'RM','LM','LW'
'LCB','RCB'		'LM', 'LWB'	'RWB','RCB','CM','CF'		

Table 9: PSG vs Marseille Start of Corner Kick: Figure (9)

PSG Inside PA	PSG Inside GA	PSG Outside PA	Marseille Inside PA	Marseille Inside GA	Marseille Outside PA
4	0	5	6	1	5
'LW','CF'	-	'RM','RW'	'GK','RW','RWB'	'GK'	'CF','LCB'
'RCB','LCB'		'CM','LM','LWB'	'LWB','RCB','CM'		'RM','LM','LW'

Table 10: PSG vs Marseille End of Corner Kick: Figure (9)

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PSG Inside PA	PSG Inside GA	PSG Outside PA	Marseille Inside PA	Marseille Inside GA	Marseille Outside PA
9	2	2	5	0	2
'LCB','GK','RWB'	'GK'	'RW', 'LW'	'LCB','RCB'	-	'RWB', 'LW'
'CM','RCB','RM','LWB'			'CM','CF','RW'		

Table 11: PSG vs Marseille Start of Corner Kick: Figure (10)

PSG Inside PA	PSG Inside GA	PSG Outside PA	Marseille Inside PA	Marseille Inside GA	Marseille Outside PA
9	2	2	5	0	2
'LCB','GK','RWB'	'GK'	'RW', 'LW'	'LCB','RCB'	-	'RWB', 'LW'
'CM','RCB','RM','LWB'			'CM','CF','RW'		

Table 12: PSG vs Marseille End of Corner Kick: Figure (10)

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PSG Inside PA	PSG Inside GA	PSG Outside PA	Marseille Inside PA	Marseille Inside GA	Marseille Outside PA
10	2	1	5	0	3
'RW','RWB','RM'	'GK','RCB'	'LW'	'CF','CM','LCB'		'RWB','RM'
'LWB','GK','RCB','LM'					

Table 13: PSG vs Marseille Start of Corner Kick: Figure (11)

PSG Inside PA	PSG Inside GA	PSG Outside PA	Marseille Inside PA	Marseille Inside GA	Marseille Outside PA
10	2	1	6	0	3
'RW','RWB','RM'	'GK','RCB'	'LW'	'CF','CM','LCB'		'RWB','RM'
'LWB','GK','RCB','LM'					

Table 14: PSG vs Marseille End of Corner Kick: Figure (11)

Bayern Munich vs Borussia Dortmund

Bayern Inside PA	Bayern Inside GA	Bayern Outside PA	Dortmund Inside PA	Dortmund Inside GA	Dortmund Outside PA
8	4	2	6	0	3
GK','RWB','RCB','RM' 'LM','LCB','CF'	'GK','RCB','LCB'	'RW','LWB'	'LM','RM', 'RCB' 'LCB','CF'	-	'RW', 'LW' 'RWB'

Table 15: Bayern Munich vs Borussia Dortmund Start of Corner Kick: Figure (13)

Bayern Inside PA	Bayern Inside GA	Bayern Outside PA	Dortmund Inside PA	Dortmund Inside GA	Dortmund Outside PA
9	3	2	5	0	2
GK','RWB','LWB','RCB' 'LM','LCB','CF','RM'	'GK','RWB', 'LCB'	'RW' 'LW'	'RM','LCB' 'CF','RCB'	-	'LW' 'RWB'

Table 16: Bayern Munich vs Borussia Dortmund End of Corner Kick: Figure (13)

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Bayern Inside PA	Bayern Inside GA	Bayern Outside PA	Dortmund Inside PA	Dortmund Inside GA	Dortmund Outside PA
0	0	5	1	0	5
-	-	'LW','RW', 'CF','RM','CM'	'LCB'	-	'RWB','LM', 'RCB','LWB','RW'

Table 17: Bayern Munich vs Borussia Dortmund Start of Corner Kick: Figure(14)

Bayern Inside PA	Bayern Inside GA	Bayern Outside PA	Dortmund Inside PA	Dortmund Inside GA	Dortmund Outside PA
0	0	5	1	0	5
-	-	'LW','RW', 'CF','RM','CM'	'LCB'	-	'RWB','LM', 'RCB','LWB','RW'

Table 18: Bayern Munich vs Borussia Dortmund End of Corner Kick: Figure (14)

Liverpool vs Manchester City

Liverpool Inside PA	Liverpool Inside GA	Liverpool Outside PA	City Inside PA	City Inside GA	City Outside PA
7	1	4	5	0	4
'RCB','CM','LCB' 'LWB','RWB','LM','CF'	'LM'	'LW','GK' 'RM','RW'	'CM','RW' 'LCB','LW'	-	'LM' 'RCB','RWB'

Table 19: Liverpool vs Manchester City Start of Corner Kick: Figure(16)

Liverpool Inside PA	Liverpool Inside GA	Liverpool Outside PA	City Inside PA	City Inside GA	City Outside PA
9	1	2	5	0	2
'RCB','LM','GK','LCB' 'CM','RWB','LWB','RM'	'GK'	'LW','RW'	'CM','CF' 'LCB','RW'	-	'LW'

Table 20: Liverpool vs Manchester City End of Corner Kick: Figure (16)

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Liverpool Inside PA	Liverpool Inside GA	Liverpool Outside PA	City Inside PA	City Inside GA	City Outside PA
7	1	3	3	0	4
'LM', 'RCB' 'LW','LWB','CM'	'LM'	'RWB','GK','RW'	'LW','LCB','RW'	-	'RCB','CF','CM'

Table 21: Liverpool vs Manchester City Start of Corner Kick: Figure(17)

Liverpool Inside PA	Liverpool Inside GA	Liverpool Outside PA	City Inside PA	City Inside GA	City Outside PA
9	1	2	5	0	2
'CM','RWB','RCB','LCB' 'GK','LM','RM','LWB'	'GK'	'LW','RW'	'LCB','CM' 'RCB','RW','CF'	-	'LW'

Table 22: Liverpool vs Manchester City End of Corner Kick: Figure (17)

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Liverpool Inside PA	Liverpool Inside GA	Liverpool Outside PA	City Inside PA	City Inside GA	City Outside PA
2	0	8	0	0	4
'RCB','LCB'	-	'RW', 'CF','RM','LWB' 'CM','GK','RWB','LM'	-	-	'RW','CF' 'LM','LW'

Table 23: Liverpool vs Manchester City Start of Corner Kick: Figure(18)

Liverpool Inside PA	Liverpool Inside GA	Liverpool Outside PA	City Inside PA	City Inside GA	City Outside PA
2	0	8	0	0	4
'RCB','LCB'	-	'RW', 'CF','RM','LWB' 'CM','GK','RWB','LM'	-	-	'RW','CF' 'LM','LW'

Table 24: Liverpool vs Manchester City End of Corner Kick: Figure (18)

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Barcelona vs Real Madrid

Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA	Real Inside PA	Real Inside GA	Real Outside PA
7	2	2	0	0	7
'CM','RWB','GK' 'LW','CF','LCB','RCB'	'GK','CF'	'RM','LWB'	-	-	'CM','LM', 'RWB','RCB' 'RW','RM','CF'

Table 25: Barcelona vs Real Madrid Start of Corner Kick: Figure(20a)

Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA	Real Inside PA	Real Inside GA	Real Outside PA
9	3	1	6	1	1
'CF','LW','GK','RM' 'RCB','RWB','LCB','LM','CM'	'LW','GK','RCB'	'LWB'	'RWB','RM','RCB' 'LW','RW','CF'	'RCB'	'LM

Table 26: Barcelona vs Real Madrid End of Corner Kick: Figure (20a)

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Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA	Real Inside PA	Real Inside GA	Real Outside PA
5	1	3	3	0	4
'CM','LCB' 'GK','CF','RCB'	'GK'	'RW','LWB','RM'	'CM','RW','LW'	-	'RCB','CF','RWB'

Table 27: Barcelona vs Real Madrid Start of Corner Kick: Figure(20b)

Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA	Real Inside PA	Real Inside GA	Real Outside PA
10	1	0	7	0	1
'LW','LM','CM','GK' 'RCB','LCB','LWB','RM','CF'	'GK'	-	'CF','LW','LCB' 'CM','RCB','RW'	-	'LM'

Table 28: Barcelona vs Real Madrid End of Corner Kick: Figure (20b)

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Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA	Real Inside PA	Real Inside GA	Real Outside PA
5 'CM','GK' 'RWB','LCB','CF'	2 'GK', 'CF'	3 RM','LW','LWB'	2 'RWB','RW'	0 -	3 LW','LCB'

Table 29: Barcelona vs Real Madrid Start of Corner Kick: Figure(20c)

Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA	Real Inside PA	Real Inside GA	Real Outside PA
9 'RWB','LCB','GK','LW' 'RCB','RM','LM','CF'	2 'GK'	2 'RW','LWB'	5 'RWB','RM' 'CF','RW'	0 -	3 'LM','LWB','LW'

Table 30: Barcelona vs Real Madrid End of Corner Kick: Figure (20c)

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Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA	Real Inside PA	Real Inside GA	Real Outside PA
9 'CM','GK','RWB','LCB' 'RM','LW','RCB','CF','LM'	2 GK','CF	1 'LWB'	3 'RM','CF','RWB'	0 -	3 'LW','RCB'

Table 31: Barcelona vs Real Madrid Start of Corner Kick: Figure(20d)

Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA	Real Inside PA	Real Inside GA	Real Outside PA
9 'CM','GK','RWB','LCB' 'RM','LW','RCB','CF','LM'	2 GK','CF	1 'LWB'	5 'RM','CF','RWB' 'RW', 'RCB'	0 -	2 'LW'

Table 32: Barcelona vs Real Madrid End of Corner Kick: Figure (20d)

Real Madrid vs Barcelona

Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
2 'LW','CM'	1 'LW'	4 'RW','LCB','RWB'	4 'LM','RWB' 'LCB','CM'	2 'RWB','CM'	3 'LWB','RW','RM'

Table 33: Barcelona vs Real Madrid Start of Corner Kick: Figure(21a)

Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
7 'CF','LW','CM' 'LM','RCB','LCB'	1 'LW'	1 -	9 'LWB','RWB','LCB','CM' 'LW','RCB','RM','LM'	1 'CM'	1 'RW'

Table 34: Barcelona vs Real Madrid End of Corner Kick: Figure (21a)

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Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
3 'CM','LW'	1 'LW'	5 'LCB','LM' 'CF','RWB'	6 'RWB','RCB' 'LWB','LW','CM'	2 'RWB'	3 'LM','LCB','RM'

Table 35: Barcelona vs Real Madrid Start of Corner Kick: Figure(21b)

Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
2 'CM','LW'	1 'LW'	4 'LM','RWB','CF'	5 'RWB','RCB' 'LWB','LW','CM'	1 'RWB	3 'LM','LCB','RM'

Table 36: Barcelona vs Real Madrid End of Corner Kick: Figure (21b)

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Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
1 'LW'	0	6 'CF','CM','LCB' 'LM','RCB','RW'	7 'CF','LW','LCB' 'RM','RCB','LWB','GK'	2 'CF','GK'	2 'RW','CM'

Table 37: Barcelona vs Real Madrid Start of Corner Kick: Figure(21c)

Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
7 'CM','CF','LW' 'RW','LCB','RCB'	0 -	2 'LWB'	10 'RCB','RWB','GK','LCB' 'CF','LW','CM','LWB','RM'	2 'GK','CF'	1 "RW"

Table 38: Barcelona vs Real Madrid End of Corner Kick: Figure (21c)

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Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
0	0	5	6	3	4
-	-	'CF','RW','LCB'	'CF', 'LWB','GK' 'LW','RCB'	'CF','GK'	'LM','LCB' 'CM','RM'

Table 39: Barcelona vs Real Madrid Start of Corner Kick: Figure(21d)

Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
1	1	5	6	2	3
'RM'	'RM'	'CM','CF' 'RW','LCB'	'LWB','GK','LW' 'CF','RCB','LCB'	'GK','CF'	'LM','CM','RM'

Table 40: Barcelona vs Real Madrid End of Corner Kick: Figure (21d)

Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
2	0	5	3	1	6
'RCB', 'LW'	-	'RM', 'LM' 'LCB', 'CF'	'GK','RCB','LCB'	'GK'	'LM', 'CF', 'LW' 'CM','LWB','RM'

Table 41: Barcelona vs Real Madrid Start of Corner Kick: Figure(21e)

Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
0	0	2	2	0	1
-	-	'LW'	'RCB','LCB'		'RWB'

Table 42: Barcelona vs Real Madrid End of Corner Kick: Figure (21e)

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Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
8	2	3	5	0	3
'RCB','LWB','RWB' 'CF','RM','GK'	'LWB', GK'	'LW','LM','RW'	'RCB','LWB' 'LCB','CF'	-	'RM','LW'

Table 43: Barcelona vs Real Madrid Start of Corner Kick: Figure(22)

Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
8	1	3	5	0	2
'RCB','LWB','LM' 'CF','RM','GK'	'GK'	'LW','RW'	'LWB', 'LCB' 'LW', 'CF'	-	'RM'

Table 44: Barcelona vs Real Madrid End of Corner Kick: Figure (22)

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Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
6	2	3	5	2	4
'CM','RWB' 'RCB','LCB'	-	'LW','RW','LM'	'CF','LW','LCB'	'CF'	'RW','LM' 'RWB','LWB'

Table 45: Barcelona vs Real Madrid Start of Corner Kick: Figure(23)

Real Inside PA	Real Inside GA	Real Outside PA	Barcelona Inside PA	Barcelona Inside GA	Barcelona Outside PA
8	2	2	6	3	2
'LWB','RWB','RCB' 'RM','CM','LCB','CF'	'LWB','LCB'	'RW','LM'	'LW','CM' 'RCB','LCB'	'RCB'	'LWB'

Table 46: Barcelona vs Real Madrid End of Corner Kick: Figure (23)

Juventus vs Inter

Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
4	0	4	8	4	3
'LCB','RW' 'LW','CF		'RM', 'LWB','RCB'	'RM','GK','LW' 'RCB', 'LCB','RF','CM'	'GK','RCB','RF'	'LM','CB','LF'

Table 47: Juventus vs Inter Start of Corner Kick: Figure(25a)

Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
6	0	3	8	3	2
'LCB','LWB','CF'	-	'RM','LW','RW'	'CM','RCB' 'GK','CB','LW'	'CM','GK'	'RW','LM'

Table 48: Juventus vs Inter End of Corner Kick: Figure (25a)

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Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
3 'LCB','LWB','CF'	0 -	5 'RM','LW','RW'	8 'CM','RCB' 'GK','CB','LW'	4 'CM','GK'	3 'RW','LM'

Table 49: Juventus vs Inter Start of Corner Kick: Figure(25b)

Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
5 'LCB','LWB','CF'	0 -	3 'RM','RW'	8 'CM','RCB' 'GK','CB','LW'	4 'CM','GK'	3 'RW','LM','LF'

Table 50: Juventus vs Inter End of Corner Kick: Figure (25b)

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Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
3 'LCB','LWB','CF'	0 -	4 'CM','RM','RCB'	7 'CB','CM','RF' 'GK','LW','RM','RCB'	1 'GK'	4 'LM', 'RW', 'LF'

Table 51: Juventus vs Inter Start of Corner Kick: Figure(25c)

Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
4 'LCB','LWB 'RCB','CF'	0 -	3 'CM','RM'	7 'CB', 'CM','RF','GK' 'LW','RM','RCB'	1 'GK'	4 'LM','RW','LF'

Table 52: Juventus vs Inter End of Corner Kick: Figure (25c)

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Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
2 'RM','RWB'	1 'RWB'	5 'RW','LCB' 'LW','CF','LM'	4 'RF','LCB' 'GK','LM'	3 'RF','LCB','GK'	7 'LF','RM' 'CM','RW','LW'

Table 53: Juventus vs Inter Start of Corner Kick: Figure(25d)

Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
2	0	5	4	2	7
'RM','RWB'	-	'RW','LCB' 'LW','CF','LM'	'RF','LCB' 'GK','LM'	'RF','GK'	'LF','RM' 'CM','RW','LW'

Table 54: Juventus vs Inter End of Corner Kick: Figure (25d)

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Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
10	2	1	7	0	3
'RWB','CF','GK','LW' 'RCB','RM','LM','CM','LCB'	'RWB','GK'	'RW'	'CB','LF' 'RM','RW','LCB'	-	'LM','CM','RCB'

Table 55: Juventus vs Inter Start of Corner Kick: Figure(26)

Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
10	2	1	8	0	2
'RWB','CF','GK','LW' 'RCB','RM','LM','CM','LCB'	'RWB','GK'	'RW'	'CB', 'RCB', 'LF' 'RM','RW','LCB'	-	'LM','CM'

Table 56: Juventus vs Inter End of Corner Kick: Figure (26)

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Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
9	1	1	4	1	5
'LCB','CM','LW','RCB' 'RM','CF','RWB','GK','LWB'	"GK"	"RW"	'LCB','RCB', 'RF'	-	'LW','CM' 'LF','CB'

Table 57: Juventus vs Inter Start of Corner Kick: Figure(27)

Juventus Inside PA	Juventus Inside GA	Juventus Outside PA	Inter Inside PA	Inter Inside GA	Inter Outside PA
10	2	0	6	0	4
'CM','RWB','RW','RM' 'LW','CF','GK','LWB','LM'	'GK','LM'	-	'LCB','LF' 'CB','RCB','RF'	-	'LW','CM'

Table 58: Juventus vs Inter End of Corner Kick: Figure (27)

Manchester City vs Liverpool

City Inside PA	City Inside GA	City Outside PA	Liverpool Inside PA	Liverpool Inside GA	Liverpool Outside PA
9	3	2	6	1	2
'LM','RM','LW','GK' 'CM','LWB','RWB','LCB'	'RM','GK'	'SUB','RW'	'CF','RM' 'LM','LW'	'RM'	'RW'

Table 59: Manchester City vs Liverpool Start of Corner Kick: Figure(29)

City Inside PA	City Inside GA	City Outside PA	Liverpool Inside PA	Liverpool Inside GA	Liverpool Outside PA
9	5	1	5	1	2
'LM','RM','LW','GK' 'CM','LWB','RWB'	'CM','GK','RWB'	'RW'	'CF','RM' 'LM','LW'	-	'RW','RWB'

Table 60: Manchester City vs Liverpool End of Corner Kick: Figure (29)

5.3 Defending Tactics

According to the methodology used in section [**"ref –subsubsec:defendingtactics"**], the defensive strategy of a team is analyzed and categorized as either man-marking or zonal defending. For this purpose, varying distance thresholds are examined. Each team's defensive strategy against a corner kick is obtained and can be below. The following format applies for each distance d = [1 m, 1.5 m, 2 m]:
how many times the strategy is observed * [man marking, zonal defenders]

Inter

d = 1	d = 1.5	d = 2
1 * [3,6]	1 * [6,3]	2 * [6,3]
3 * [2,7]	2 * [4,5]	1 * [6,2]
1 * [1,7]	1 * [4,4]	3 * [5,4]
1 * [1,8]	1 * [2,7]	
	1 * [1,8]	

Table 61: Inter Defending Strategy Analysis

Juventus

d = 1	d = 1.5	d = 2
3 * [1,8]	1 * [3,6]	1 * [6,3]
1 * [1,7]	1 * [3,5]	1 * [3,6]
	1 * [2,7]	1 * [3,5]
	1 * [1,8]	1 * [2,7]

Table 62: Juventus Defending Strategy Analysis

PSG

d = 1	d = 1.5	d = 2
1 * [1,8]	1 * [3,6]	1 * [6,3]
1 * [0,9]	1 * [2,7]	1 * [3,6]

Table 63: PSG Defending Strategy Analysis

Marseille

d = 1	d = 1.5	d = 2
1 * [1,8]	1 * [1,8]	1 * [2,7]

Table 64: Marseille Defending Strategy Analysis

Bayern Munich

d = 1	d = 1.5	d = 2
1 * [0,9]	1 * [1,8]	1 * [2,7]
1 * [0,3]	1 * [0,3]	1 * [0,3]

Table 65: Bayern Munich Defending Strategy Analysis

Liverpool

d = 1	d = 1.5	d = 2
1 * [2,7]	1 * [3,6]	1 * [6,3]
1 * [0,9]	1 * [2,7]	1 * [3,5]
1 * [0,8]	1 * [0,8]	1 * [0,8]

Table 66: Liverpool Defending Strategy Analysis

Manchester City

d = 1	d = 1.5	d = 2
1 * [1,7]	1 * [4,4]	1 * [6,2]

Table 67: Manchester City Defending Strategy Analysis

Barcelona

d = 1	d = 1.5	d = 2
1 * [4,4]	1 * [5,4]	1 * [7,2]
1 * [3,6]	1 * [5,3]	1 * [7,1]
1 * [3,5]	1 * [4,5]	1 * [6,3]
1 * [2,7]	1 * [4,4]	1 * [5,1]
2 * [2,6]	2 * [3,5]	3 * [4,4]
1 * [1,5]	1 * [3,3]	1 * [3,4]
1 * [0,7]	1 * [2,5]	1 * [0,1]
1 * [0,1]	1 * [0,1]	

Table 68: Barcelona Defending Strategy Analysis

Real Madrid

d = 1	d = 1.5	d = 2
1 * [5,3]	1 * [5,3]	1 * [6,2]
1 * [3,6]	1 * [4,5]	1 * [4,5]

Table 69: Real Madrid Defending Strategy Analysis

5.4 Positioning of Players

According to the methodology used in 2.3.4, the strategical positioning of the defending team's players are revealed. Each cluster is represented with a distinct color. Cluster centroids are represented with black dots. Below, you can see the k-means clustering results for each defending team.

Inter

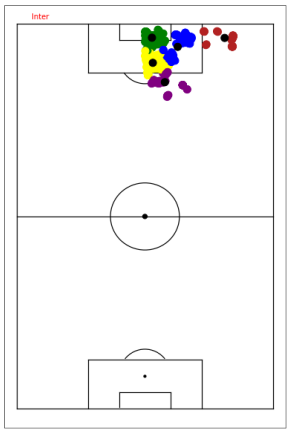

Figure 30: Inter player positioning, k = 5

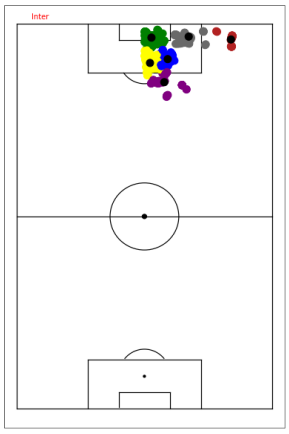

Figure 31: Inter player positioning, k = 6

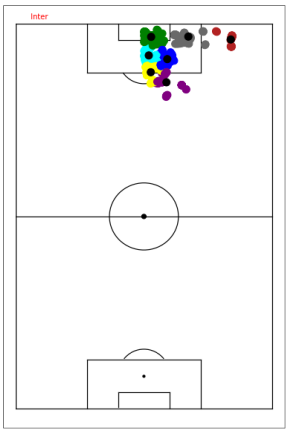

Figure 32: Inter player positioning, k = 7

Figure 33: Player positioning of Inter in the corner kicks

Juventus

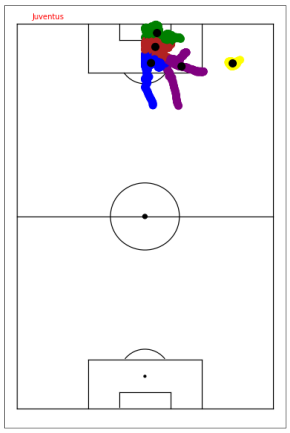

Figure 34: Juventus player positioning, k = 5

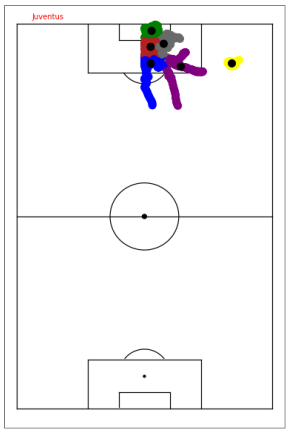

Figure 35: Juventus player positioning, k = 6

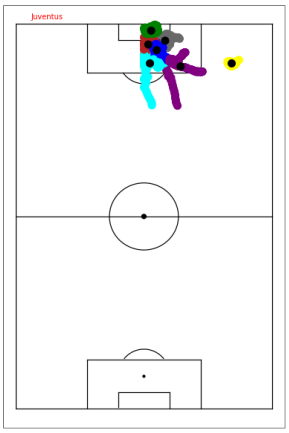

Figure 36: Juventus player positioning, k = 7

Figure 37: Player positioning of Juventus in the corner kicks

PSG

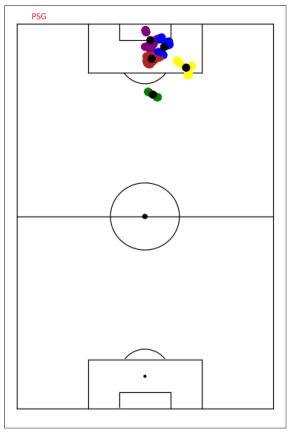

Figure 38: PSG player positioning, k = 5

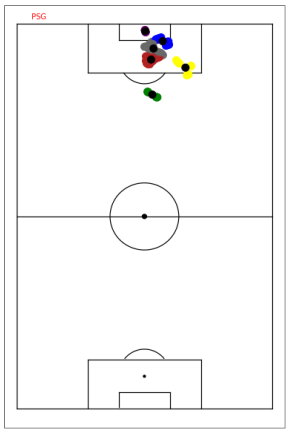

Figure 39: PSG player positioning, k = 6

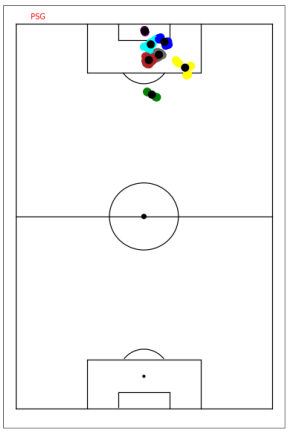

Figure 40: PSG player positioning, k = 7

Figure 41: Player positioning of PSG in the corner kicks

Marseille

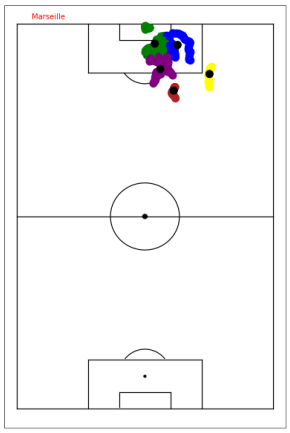

Figure 42: Marseille player positioning, k = 5

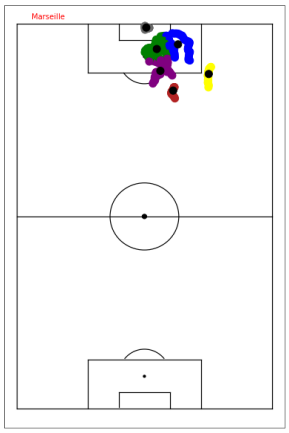

Figure 43: Marseille player positioning, k = 6

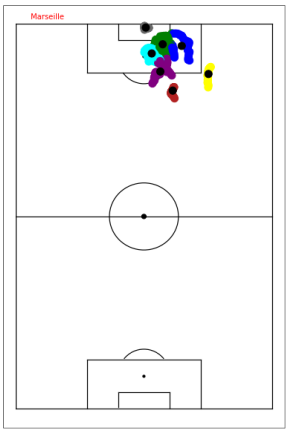

Figure 44: Marseille player positioning, k = 7

Figure 45: Player positioning of Marseille in the corner kicks

Bayern Munich

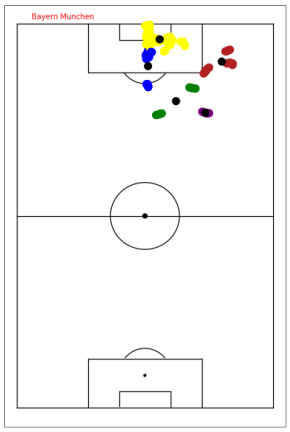

Figure 46: Bayern Munich player positioning, k = 5

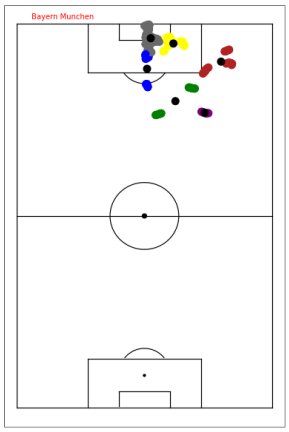

Figure 47: Bayern Munich player positioning, k = 6

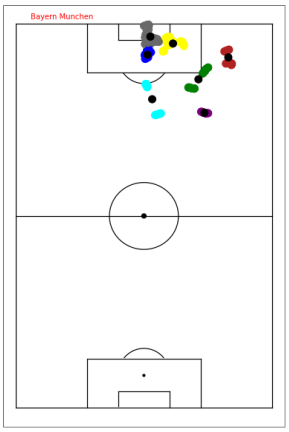

Figure 48: Bayern Munich player positioning, k = 7

Figure 49: Player positioning of Bayern Munich in the corner kicks

Liverpool

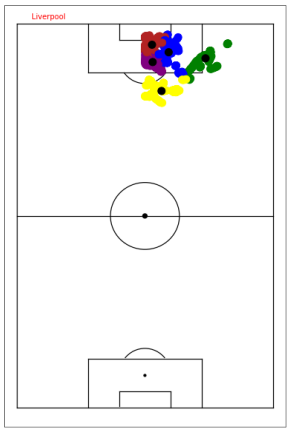

Figure 50: Liverpool player positioning, k = 5

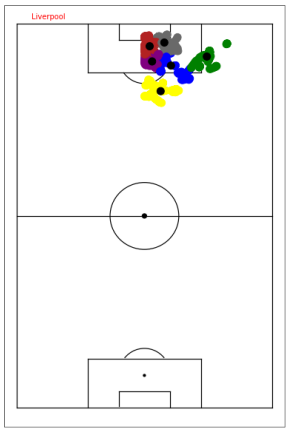

Figure 51: Liverpool player positioning, k = 6

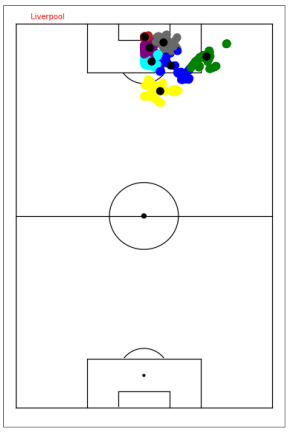

Figure 52: Liverpool player positioning, k = 7

Figure 53: Player positioning of Liverpool in the corner kicks

Manchester City

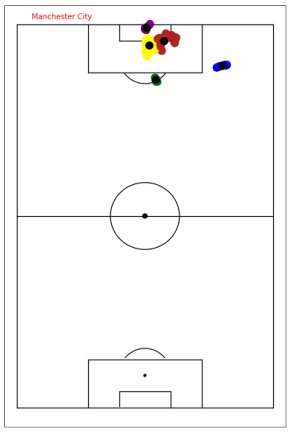

Figure 54: Manchester City player positioning, k = 5

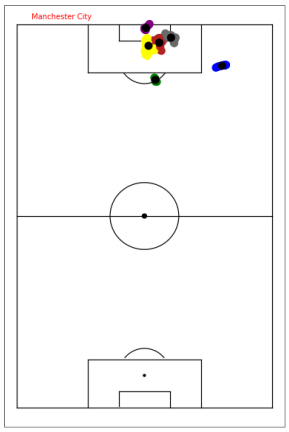

Figure 55: Manchester City player positioning, k = 6

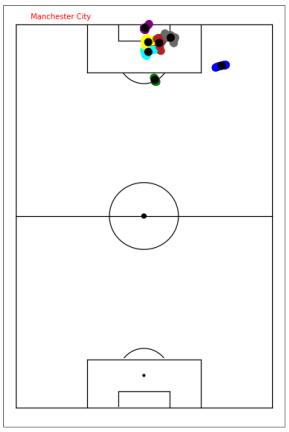

Figure 56: Manchester City player positioning, k = 7

Figure 57: Player positioning of Manchester City in the corner kicks

Real Madrid

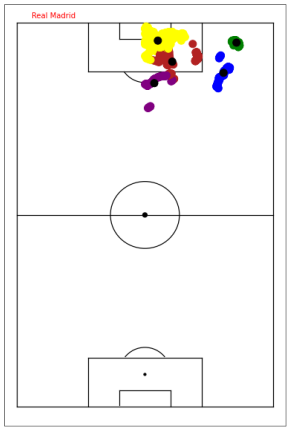

Figure 58: Real Madrid player positioning, k = 5

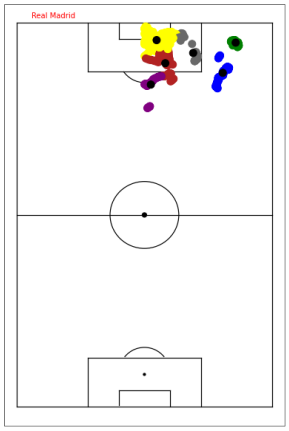

Figure 59: Real Madrid player positioning, k = 6

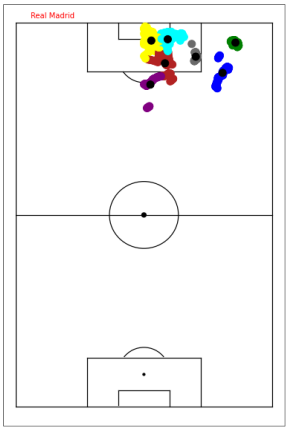

Figure 60: Real Madrid player positioning, k = 7

Figure 61: Player positioning of Real Madrid in the corner kicks

6 Discussion

In this section, for each model and analysis, the reason for choosing the methodology, pros and cons of the approach and possible improvements with more time and data is discussed.

6.1 Corner Kick Identification

According to the International Football Association, the rules for corner kicks are defined [4]. Detecting the frames of corner kick events is crucial, and the methodology employed here follows these rules. However, complete data is necessary to accurately verify the rules. Unfortunately, the dataset lacks consistent information on player and ball locations. Moreover, defensive players may not strictly adhere to the 9.15-meter rule, as this distance can vary during the game. Consequently, the identification conditions for corner kicks are slightly relaxed. The ball's position is not considered to avoid missing any corner kick events, and the opponent's distance to the corner arc is taken as 9 meters, allowing for some flexibility. This approach may result in classifying some non-corner kick events as corner kicks, since ball coordinates and game state information are not provided. However, with more comprehensive data, the rules of the International Football Association can be applied strictly, reducing misclassification. After detecting each corner kick event, complete data enables the accurate analysis of the start and end of the corner routine using a larger window.

6.2 Distribution of Players

The distribution of players during corner kicks is important for multiple reasons. It reveals player roles and positioning in these situations. Typically, players proficient in heading are placed inside the penalty area, while those skilled in shooting with their feet position themselves near the penalty arc. Defensively, faster players often occupy positions near the penalty arc for potential counter-attacks. Analyzing the start and end frames of corner kicks unveils the attacking team's strategy. A significant increase in players within the penalty or goal area suggests the use of decoy runs, while static positioning implies a different approach. Players adapting to defined zones are crucial as they create space or become key shooters. Understanding their movements and positions provides insights into the attacking team's intentions and scoring opportunities.

In some corner routines, certain players' roles may be absent, and detected routines may be shorter, making it difficult to observe significant changes. However, a larger and complete dataset would enable precise determination of all player roles. Analyzing corner kick routines within wider windows allows for accurate investigation of player distributions. This reveals a team's corner kick strategy more clearly.

6.3 Defending Tactics

This approach significantly highlights how a team positions themselves during a corner kick. In the previous approach, the attacking team's strategy was observed in terms of decoy runs or static positioning. Therefore, it is crucial to analyze the opponent's defensive perspective and determine whether they employ a man marking or zonal defending strategy. The key factor that can vary based on a coach's perspective is the distance between two players, which determines whether the defending action is classified as man marking or zonal defending. Hence, the analysis is conducted with varying distance values.

Additionally, the level of adherence to a particular tactic by a team can be observed. If the number of man marking defenders remains relatively constant even as the distance decreases, it suggests that the team is likely employing a man marking strategy. The results of this methodology are obtained based on the last observed frame of each corner kick event. An improvement for the methodology could involve observing and analyzing the changes in the number of man markers and zonal defenders throughout the entire corner kick routine. However, this would require more time and a more comprehensive dataset.

6.4 Player Positioning

The player positioning methodology employs an unsupervised machine learning model, specifically k-means clustering. The objective is to identify the crucial locations where a defending team positions themselves. To achieve this, corner kicks taken against a team are detected, and the spatial locations of the defending team's players are recorded. Each data point is treated equally in the analysis.

To assign data points accurately to clusters and achieve a meaningful division of the data, the k-means algorithm is run with various values of k. A basic interpretation is as follows: if k players are involved in the corner kick routine, each centroid represents the most probable locations where these players would position themselves. It is important to note that the number of clusters does not necessarily have to match the number of players in order to analyze the results.

The key aspect of determining the number of clusters is to assign data points in a way that points closer to each other are grouped within the same cluster, creating meaningful zonal distributions from a football perspective. In other words, the variance of players within a cluster should be minimized. The choice of the number of clusters depends on the team and the available data. With more data and time, the optimal number of clusters can be investigated, leading to more accurate identification of key locations for a defending team during corner kick events.

It should be noted that some teams may have fewer corner kicks in the dataset, resulting in less informative results. A more comprehensive dataset would increase the number of detected corner kick routines, providing more accurate and extensive analysis.

6.5 Possible Improvements

In the paper with the title "Routine Inspection: A playbook for corner kicks"[3], there are two methodologies applied to analyze corner kicks. The first one uses Gaussian mixture modelling to classify attacking player runs into tuples based on their start and end locations [3]. The latter one applies a topic model (using non-negative matrix factorization) to identify runs that frequently co- occur in corner routines [3]. With more time and comprehensive data, I would have applied these methodologies.

7 Conclusion

In conclusion, this study focused on the identification and analysis of corner kicks in order to gain insights into patterns, strategies, and player movements that contribute to goal-scoring opportunities. By examining how opposing teams approach both attacking and defending corner kicks, valuable vulnerabilities can be identified and exploited in future matchups. The project was implemented using Python, with the goal of providing practical insights to optimize corner kick strategies. Corner kicks were identified by combining the definition provided by IFAB [4] and the methodology outlined in the Automatic Event Detection paper [5]. The analysis delved into the distribution of players across different zones, defensive tactics, and player positioning. The methodologies were tested using data provided by SkillCorner. Overall, this research offers valuable insights that can inform teams' decision-making processes and enhance their corner kick strategies.

8 APPENDIX

8.1 Data Parsing

The data is provided by SkillCorner and contains 9 matches. To be able to use the given data, a parsing section is essential. To serve this purpose, three data parsing classes are implemented to utilize the "matches.json" file and ("match_data.json", "structured_data") files for each match.

8.1.1 Matches Data Parser

The matches data is a ".json" file including the basic information of the matches in the dataset [1]. A parser class is implemented to store the information of each

match. For each match, the match ID, the date of the match and name of the teams are stored.

8.1.2 Match Data Parser

For each match, there is a ".json" file including the information regarding the match [1]. A parser class is implemented to obtain the relevant information for analysis. The object fetches the match ID, date of the match, team names, team IDs, pitch dimensions, match score, player names, player's trackable object values, player jersey numbers, player roles, match start time and match end time. The object of this class is created for each match.

8.1.3 Tracking Data Parser

For each match, there is a ".json" file including the tracking information regarding both teams [1]. A parser class is implemented to obtain the relevant information for analysis. In order to detect whether the game is in play and the data is available, the period of each frame is checked together with the length of the location data. If the period value is valid and there exists a location data, then the corresponding frame, possession info, player locations and their trackable object values and ball location are stored. Besides this, without checking the availability of the spatial data, the raw version of the tracking data is also stored. The object of this class is created for each match.

References

[1] *data*. URL: https://github.com/SkillCorner/opendata.

[2] *pitch*. URL: https://publications.fifa.com/en/football-stadiums-guidelines/technical-guideline/stadium-guidelines/pitch-dimensions-and-surrounding-areas/.

[3] Laurie Shaw. "Routine Inspection: A playbook for corner kicks". In: *MIT SLOAN SPORTS ANALYTICS CONFERENCE* (2021).

[4] *thefa*. URL: https://www.thefa.com/football-rules-governance/lawsandrules/laws/football-11-11/law-17---the-corner-kick.

[5] Ferran Vidal-Codina1 et al. "Automatic event detection in football using tracking data". In: *Sports Engineering* (2022).