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Mathematical model of football goal's hazardous area based on matlab simulation

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ABSTRACT

This paper studies the threat degree of shot goal in different locations for the football game players and maps out the dangerous zone of the goal. Under certain conditions, for the same quality players shooting at any point on the field, we mainly study the goal threat degree and define the threat degree as the successful goal probability. This paper studies the hazardous area problem in both cases with goalkeepers and without goalkeepers in football door, establishes a one-dimensional normal model and two-dimensional normal distribution model using football rules and carries through model simulation and analysis with MATLAB software. Studies have shown that the successful shot goal position on the pitch of the players is normally distributed. The shot path of any point on the pitch of the players is decomposed into horizontal and vertical direction. The angle alpha and beta are introduced to build two one-dimensional normal distribution models. In the defense case with a goalkeeper, we further study the players' shot threat degree and dangerous zone to re-establish the two-dimensional normal distribution model of the alpha and beta.

KEYWORDS

Hazardous areas;
MATLAB;
Football;
Mathematical model.

INTRODUCTION

The ultimate goal of the football match is to goal and win. The pros and cons of the shot quality of a football team and the ability to grasp the scoring opportunities will directly affect the team scores. With the scholars' in-depth exploration on the football field, there is a growing emphasis on the exploration of football door hazardous area, and people on this guidance arrange football training content, so that the football training methods and means can be more scientific and reasonable. In football, offensive and defensive form a contradiction. The offensive side always uses a variety of tactics to break through the other side's defense, create scoring chances to achieve the purpose of field goal. While the defensive side forms a defense system with a different tactics in front of this side, set up obstacles to the offensive players, strangle other side's scoring chances to ensure the safety of the door.

Chen Ruining (2010) pointed out: the penalty area is goal-prone areas, followed by the cutting-edge area of the penalty area, indicating that the goal area and shot area is closely related, the larger the number of shots is, the greater the goals increase, which is in line with the basic rules of the game. ZHONG Jun[12] pointed out: the shot effect of different regions is different; the front shot is the main means of scoring. Wang Xin[8] pointed out: the best shot area includes: 20-25 meters from the goal, the angle with the goal is 40-45 degrees, taking the midpoint of the goal line as the center, the shot effectiveness of this area is about 65%. Wang Dachuan[9] pointed out: from the perspective of shot region, the penalty area is the central area of the goal, in the penalty area it is not the closer from the goal the higher the score becomes, but it is easier to break near the penalty spot. Because at this time the shooting angle is bigger, the goalkeeper is difficult to control, defensive density is relatively small in front of the goal area, and therefore there is less interference. Yao Kai (2007) pointed out that the goal is higher shot from the left half court than the right half court of the total field area; the small restricted area is nearest to the goal, and the shooting angle is the biggest; but at the same time it is nearest from the goalkeeper, and the defense is over-intensive, so the goal is not much; the shot angle of large restricted area is large, the shot distance is moderate, so the large restricted area is the area of most goals. Shi Zhi-she and Cao Wei-min (2000) pointed out that among the high level football game of the world today, the most threatening shot area is the area within 30 meters of the front goal; especially shot in the restricted area faced to the goal, the scoring rate is the highest.

This paper uses MATLAB software to conduct simulation and analysis to the model, and establish a one-dimensional normal model and two-dimensional normal distribution model using football rules.

PROBLEM ANALYSIS

To determine the danger zone of the football gate, that is to determine the area for players to shot the easiest goal. We must first study the likelihood of goal success when the player is shooting at any position. Regardless of the position from which players shot, there are two possibilities in or not in, and itself is a random event. There are many factors that affect the player's success goal rate, the most important of which is the basic quality of the players and the shot location. For each player, the basic quality cannot be changed in the short-term, so we think the basic quality of the players is the same or doesn't differ much. Therefore, under certain conditions, we conduct analysis on the players' shot location; research the relationship between players' shot location and success goal rate, i.e., the threat degree of the players on the goal.

In the case without goalkeeper, when the player is to shoot the ball to the goal in a location, this player; basic quality and the distance from the player' location to the goal determine the success goal probability. When the players score successfully on the pitch, the ball location when shooting has a fixed probability distribution; after a brief analysis it is easy to judge the distribution is normal. Here the shot path of the players on the pitch at any position is decomposed into horizontal and vertical direction. Simply multiplied by the hit goal probability of both directions, you can get the goal probability of the players at certain point on the pitch. This probability can be used to define the threat degree to the goal of this point.

In the case of having goalkeeper, in addition to the above analysis, we need to analyze the successful shot goal probability of the goalkeeper. The football flies to the goal after the players shot from the other side. When the goalkeeper is in defense, one needs a certain reaction time. So we establish a two-dimensional normal distribution model on the basis of no goalkeeper.

BASIC ASSUMPTIONS AND SYMBOL DESCRIPTION

Assumptions:

(1) In the ideal situation, the basic quality of the players is the same or not very different;
(2) Does not consider the impact of the air and the ground to the ball speed after the shot, the ball speed is set to 10 m / s;
(3) The players only shot in the front court, assume that the front court is the effective shooting area;
(4) consider only the standard course $(104\times 69)m^2$ and goal $(7.32\times 2.44)m^2$;
(5) The ball shooting toward the goal is in straight path, and it does not consider the case of a parabola.

Symbol description:

π —The plane of the goal;

α —The shot angle of the players at a point on the court in horizontal direction;

β —The shot angle of the players at a point on the court in vertical direction;

$A(x, y)$ —The shot point on the court;

$B(x, y)$ —The point within the goal;

f_1 —The shot goal probability of the players at a point on the court in horizontal direction;

f_2 —The shot goal probability of the players at a point on the court in vertical direction;

f —The shot goal probability of the players at a point on the court;

k_1 —The coefficient to measure the goalkeeper's angle control ability in horizontal direction;

k_2 —The coefficient to measure the goalkeeper's angle control ability in vertical direction;

t —Goalkeeper's reaction time.

THE MODEL BUILDING AND SOLVING WITHOUT GOALKEEPER

Here the shot path of the players at any position on the pitch is decomposed into horizontal and vertical direction. In the horizontal direction, the goal that the player actually sees is the projection region of the original goal on the vertical plane of the players. Therefore the player will try to shot the ball towards the midpoint of the projected goal to ensure the hit rate, which would form the probability distribution in the vicinity of the point. After a brief analysis it is easy to conclude that the distribution should be normal, which is the key to solve the problem. In the vertical direction, the players will try to drive down the ball's shot height to ensure the hit rate, which will also form a probability distribution in the vertical direction. Similarly, the distribution is a normal distribution. Particular note is that the players can actually kick the upper part of the ground; therefore the normal distribution only takes the upper half part.

We simply multiply the goal hitting probability of both directions, and can get the shot goal probability of the players at a point on the court, this probability can be used to define the threat degree of this point.

The probability density function of the continuous random variable X is:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}, -\infty < x < \infty$$

When $\mu = 0, \sigma = 1$, X complies with the standard normal distribution:

$$\varphi(x) = \frac{1}{\sqrt{2\pi}} e^{-t^2/2}$$

Model building

First establish the space Cartesian coordinate system shown in Figure 1, take the corner ball point in the right-side of the court as the original point O. The ground is the xoy surface; the plane π of the goal is the xoz surface.

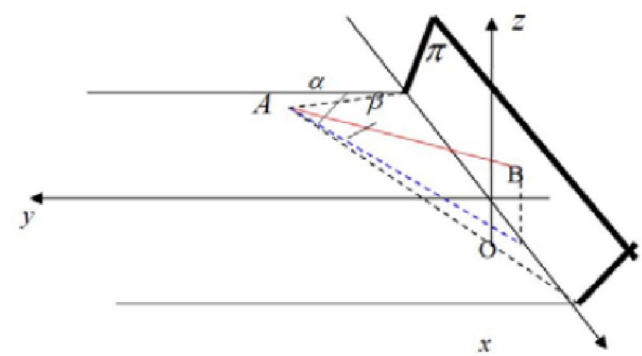

Figure 1 : The schematic diagram of the goal

According to the above analysis, the hitting goal probability of the players in the horizontal direction satisfies $X \sim N(90, 5^2)$:

Expectation of players is shooting facing the goal and the shooting area angle is 90°; assume that the standard deviation of players shooting in the horizontal direction is 5°. When the shooting angle of players in the horizontal direction is α, the hitting goal probability is:

$$P\{90 - \frac{\alpha}{2} < X < 90 + \frac{\alpha}{2}\} = \phi\{\frac{-\frac{\alpha}{2}}{5} < X < \frac{\frac{\alpha}{2}}{5}\} \quad = 1 - 2 \times [1 - \phi(\frac{\frac{\alpha}{2}}{5})]$$

Transfer the shooting angle of the players into the standard normal, then use Matlab to calculate the goal probability f_1 of each point in the horizontal direction of the court. Accordingly, the goal probability in the vertical direction meets $X \sim N(0, 2.5^2)$:

The players will try to kick the ball low and flat in order to increase the goal probability. It is assumed that the standard deviation of the players shot in the vertical direction is 2.5°. Players can actually kick the ball above the ground, after making a correction, when the shot angle of the player in vertical direction is β, the hit goal probability is:

$$P\{X < \beta\} = \phi\{X < \frac{\beta}{2.5}\} = \phi(\frac{\beta}{2.5})$$

Transform the players' shot angle into standard normal, and then calculate the shot goal probability f_2 of the players at a point on the court in vertical direction using Matlab. So we can get on the threat degree of each point on the court is $f = f_1 \times f_2$.

Model solving

Through VC program, you can respectively draw the hitting probability of the goal in horizontal and vertical directions:

Multiplied by two shot goal probabilities in the horizontal and vertical direction, we can get the hit goal probability of each point, i.e., the threat degree of each point, so that we can draw the equal threat degree curve of the court, as shown in Figure 2:

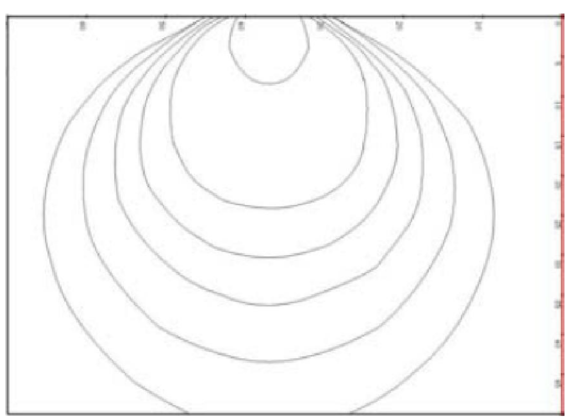

Figure 2 : Equal threat degree curve of the court

THE MODEL BUILDING AND SOLVING WITH GOALKEEPER

Assume that the goalkeeper stands on the bisector line of the angle between the shot point and the two goalposts, i.e., goalkeeper stands in the projection plane of the goal and vertical shot line; the center of the area is the best defensive position. Players shot at a point on the pitch to any point $(x, z) \in \pi$ within the goal, and after the elapsed time t it reaches the plane of the goal. When the ball arrives at the point, the goalkeeper has a diving ball probability $q(t, \alpha, \beta)$, the following analyzes the form of this function $q(t, \alpha, \beta)$.

First we notice that when t is constant, $q(t, \alpha, \beta)$ should be two-dimensional function with radiation attenuation toward the surrounding taking goalkeeper as the center, as Figure 3 and Figure 4 show the corresponding contour map.

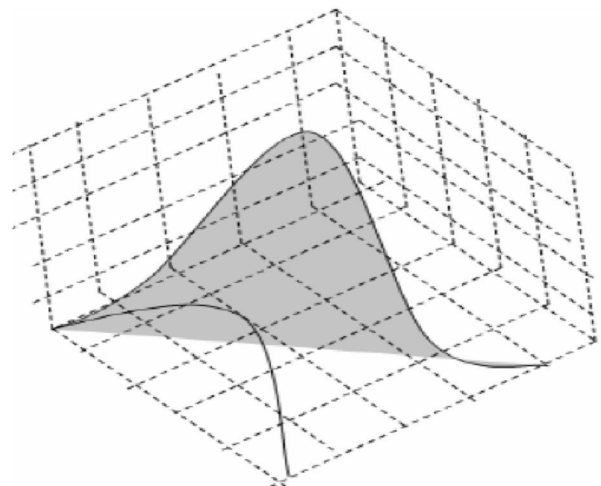

Figure 3 : The contour line three-dimensional map of the radiation attenuation two-dimensional function when t is constant

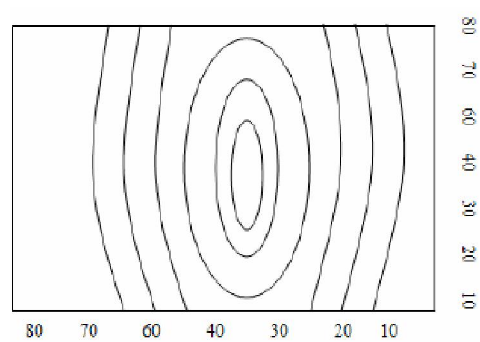

Figure 4 : The two-dimensional function contour line plan of radiation attenuation when t is constant

When t becomes smaller, the peak of the curve should be increased, while the area should be reduced, as shown in Figure 5 and Figure 6.

As can be seen from Figure 5, the form of this surface is very similar to the density function of the two-dimensional normal distribution; therefore, we use this function form to describe this trend. Parameter means the time from shooting ball to reaching the goal, i.E. the goalkeeper's reaction time. The longer the time is, the smoother the surface becomes. The successful diving ball probability for goalkeeper is:

$$q(t,\alpha,\beta)=e^{-\frac{(\frac{\alpha}{2\times k_1})^2+(\frac{\beta}{2\times k_2})^2}{(\frac{\sqrt{x^2+y^2}}{10}+t)}}$$

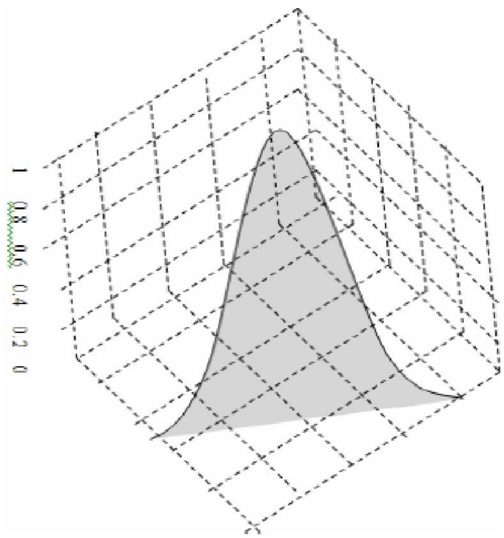

Figure 5 : The contour line three-dimensional map of the radiation attenuation two-dimensional function when t becomes smaller

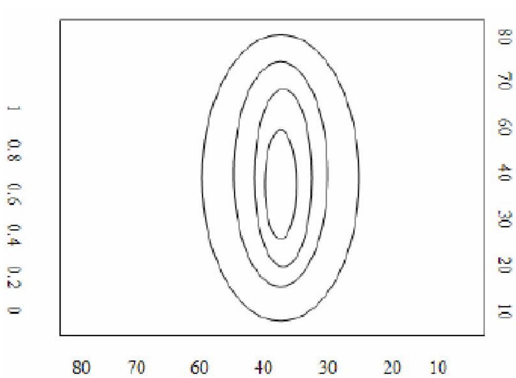

Figure 6 : The contour line average map of the radiation attenuation two-dimensional function when t becomes smaller

Among them e is the reaction coefficient of goalkeeper. According to experts' prediction, the reaction speed of normal people is about 0.12-0.15s. Based on the famous "strip test" the reaction time of normal people is about $\sqrt{2}/10s$ (that is envisaged that a piece of paper is between the two fingers. When the piece of paper falls freely under the action of gravity, the reaction time can be calculated out from $s=\frac{1}{2}gt^2$). Therefore, we may take t = 1/7 (experimental value).

k_1 means the coefficient to measure the goalkeeper's angle control ability in horizontal direction; k_2 means the coefficient to measure the goalkeeper's angle control ability in vertical direction. We get the values of k_1 0 k_2 based on a large number of statistics, here we take k_1 =20, k_2 =10.

Model building

(1) On the basis of question (1), the goal probability of the players in every point of the pitch should be amended as $f\times(1-q(t,\alpha,\beta))$. This $q(t,\alpha,\beta)$ means the probability goalkeeper spring at the ball, $1-q(t,\alpha,\beta)$ means the probability of not springing at the ball.

Model solving

Similarly to the model solving without goalkeeper, we can get the threat degree of any point on the pitch. According to the value of threat degree, the equal threat degree curve on the pitch can also be made, as shown in Figure 7.

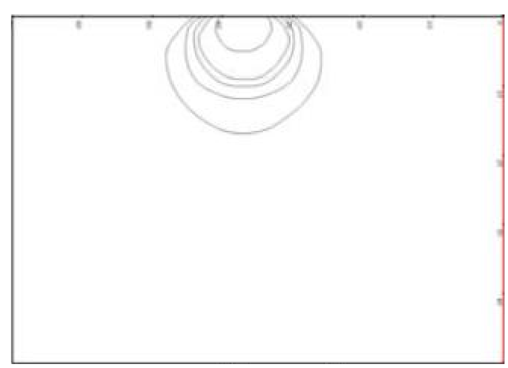

Figure 7 : The equal threat degree curve with goalkeeper

CONCLUSIONS

Compare the two situations we can see that defensive unguarded and defensive are very different. The defensive situation is mainly the role of the goalkeeper making the danger zone significantly reduced. The largest threat regional is the area near the goal, especially in the right ahead, which also explains the rationality of large and small restricted area set on the pitch.

The K value of the model is estimated, strictly speaking, it might be better to determine through a lot of experiments according to the statistics law. We prove by calculating that when K increases (i.e. the quality of the players enhances), the threat to the goal markedly increases and the danger zone becomes larger. Conversely, when K is reduced, the threat degree to the goal is also reduced, i.e. the danger zone is smaller. About the quality of the goalkeeper, it is not considered in the model in order to simplify the problem. The sending troop to embattled problem with several offensive and defensive players is even more complicated.

Due to a lot of assumptions and simplified, there may be a little deviation with actual situation. There are a variety of different solutions to the problem, for example, we can make use of elementary algebra and elementary geometry method. Carrying through stochastic simulation in different shot point and defining the threat degree function through the goal probability can also give the corresponding results.

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