http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (15): 3315-3319, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.3315.3319

Applications of Monte Carlo Algorithm in Research on the Basketball Hit Rate of Ideal Hollow Shooting Based on Matlab Simulation

Dingyu Tang, Gang Ma and Jun Guo
Institute of Physical Education, Zhaotong University, Zhaotong, 657000, China

Abstract: The hit rate of basketball shooting is an important indicator to evaluate the athlete's athletic ability. There are many factors affecting hit rate of basketball shooting including the shot location, shot angle, shot rate, the hoop position, gravity, air resistance, athlete's psychological quality and other factors. This article studies a basketball shooting mathematical model with an ideal state from a non-technical point of view, uses Monte Carlo algorithm to implement hollow shooting conditions of the model in Matlab software and provides an application platform for the application of Monte Carlo. In this study, Monte Carlo Algorithm based on Matlab Simulation get a better application in an ideal study of hollow basketball shooting providing a new way of thinking for the study of basketball hit rate.

Key words: Monte carlo, matlab simulation, basketball, mathematical model

INTRODUCTION

Monte Carlo method is a stochastic simulation method or a statistical experimental method which is based on probability statistical theory. Monte Carlo algorithm is an approximate calculation algorithm, based on the principle of using the sample mean of law of large numbers to replace the overall mean, using computer digital simulation technology to solve some complex problems which is difficult to directly be solved by math. In the nineteenth century, people used needle cast test to determine pi. With the emergence of computer, especially the high speed computer appeared in recent years, the mathematical method get simulation very conveniently repeat and quickly on the computer (Zhang and Feng, 2013). And Monte Carlo algorithms this typical stochastic simulation algorithm has also been well implemented and plays a facilitating role in solving complex problems in all walks of life (Du, 2000).

In basketball this popular sports in the world, superb shooting technique determines an athlete's technique level. Many professionals have conducted in-depth research on shooting hit rate and provide a good theoretical base for the development of this technology (Gao, 2007). Wherein research direction is divided into two kinds, one is a professional point of view; the other is expounded description from the physical point of view (Wu and *Gai*, 2003). The former is a qualitative analysis of the basketball shooting hit rate while the latter conducts a quantitative analysis on the basketball shooting hit rate using two-dimensional model instead of three-dimensional model (Avci and Avci, 2008). If study the hit rate from a physical point of view, there will be issues such as computational complexity (Li, 2004); thus the clear analysis become blurring which cannot play a very good effect on the nature of basketball shooting hit rate (Grimaldi *et al*., 2007).

This study, on the basis of previous research, presents a research method of hollow shooting hit rate based on Monte Carlo algorithm, provides a study idea for the increasing of hollow shooting hit rate and provides application platform for the extensive use of Monte Carlo algorithms.

PROBLEM ANALYSIS

Conditional analysis of hollow shooting: Under ideal conditions, basketball only suffers the force of gravity after releasing (Li *et al*., 2012). The basketball conducts projectile motion under the premise of not collision with the backboard and hoop after releasing (Liu, 2011). The key to research the hollow shooting is the relation of the relative position of the releasing position and hoop, velocity magnitude and direction of the releasing basketball, the size of basketball and basket and other factors (Zhu and Lei, 2010).

Intuitively speaking, the condition of hollow shooting is that there is no intersection of the basketball and hoop in the course of the motion and the basketball sphere needs to pass hoop; it can be constrained by the equation solution in mathematic. Figure 1 shows the schematic figure of shooting.

Corresponding Author: Dingyu Tang, Institute of Physical Education, Zhaotong University, Zhaotong, 657000, China

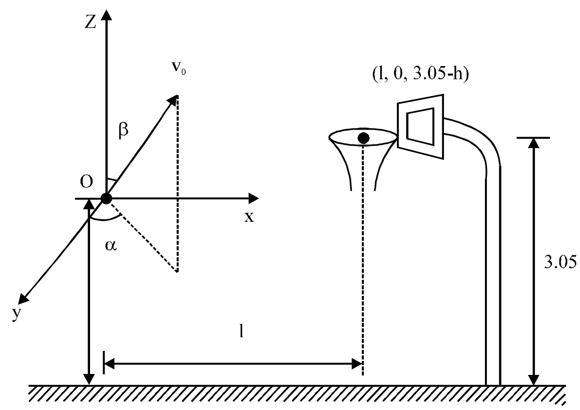

Fig. 1: Schematic figure of shooting

Model assumption:

- We only consider the gravity of basketball during motion process
- Only consider the case of a hollow ball
- The distance of basket center and ground is 3.05 m
- Basketball diameter is of 0.24 m and the diameter of basket is 0.45 m
- The position releasing basketball in the coordinate system is the origin
- The pitching point is always located in the lower part of the basket

MODEL BUILDING OF HOLLOW SHOOTING AT THE BASKET

Basketball projectile motion: The basketball only receives the force of gravity during movement, so each point on the basketball surface is relatively static. Its trajectory is parallel to the trajectory of the centroid. In order to study conveniently the basketball is divided into the movement of three directions, as the relative position shown in Fig. 1 and the parametric equation in Eq. 1:

$$\begin{cases} x(t) = v_0 \sin\beta \sin\alpha \cdot t \\ y(t) = v_0 \sin\beta \cos\alpha \cdot t \\ z(t) = v_0 \cos\beta \cdot t - \frac{1}{2}gt^2 \end{cases} \quad (1)$$

Suppose an arbitrary point of the sphere is (X(t), Y(t), Z(t))), then the point satisfies the Eq. 2:

$$(X(t)-x(t))^2+(Y(t)-y(t))^2+(Z(t)-z(t))^2 = r^2 \quad (2)$$

In Eq. 3 r represents the radius of basketball, in this study it is taken 0.12 m, the equation of basket is in Eq. 3:

$$\begin{cases} (x(t)-l)^2 + y(t)^2 = R^2 \\ z(t) = 3.05 - h \end{cases} \quad (3)$$

Conditional constraint of hollow shooting: When the shooting is a hollow ball, it needs to satisfy Eq. 4:

$$\begin{cases} (X(t)-l)^2 + Y(t)^2 \le R^2 \\ Z(t) = 3.05 - h \end{cases} \quad (4)$$

In order to satisfy the Eq. 4 the coordinates of any point on the ball surface may be written in the form of parameters, as shown in the Eq. 5 below:

$$\begin{cases} X(t) = r\sin\varphi\sin\theta + x(t) \\ y(t) = r\sin\varphi\cos\theta + y(t) \\ z(t) = r\cos\varphi + z(t) \end{cases} \quad (5)$$

The φ, θ in Eq. 5 represents two parameters with no practical significance.

MONTE CARLO ALGORITHM

Basic idea: Monte Carlo method is also known as random sample skill or statistical test method, is a calculation method based on the theory of probability statistics. This method can realistically descript the characteristics of things and events occurring process and solve some of the problems which cannot be solved by numerical method. The theory base of this method is the law of large numbers and central limit theorem.

Law of large numbers and the central limit theorem is an approach using the method of limits to study the statistical regularity of large number of random phenomena. Stating the average results of a large number of repeated trials and a series of laws with the stability is called law of large numbers. Theorem demonstrating random variables and progressive obedience a distribution is called the Central Limit Theorem.

When the solution of the problem is the probability of an event, or is the expectation of a random variable, or an parameter related with probability and mathematical expectation, through some test methods, the frequency of the incident or the mean arithmetic value of several observations of the random variable can be obtained and then get the solution of the problem according to the law of large numbers. We can use Bernoulli's law of large numbers or Chebyshev's law of large numbers, as follows:

Suppose test E repeated for n times, the probability that event A occurs in each experiment is p, the times that event A occurs is μ_n. Then for any ε>0, it satisfies the Eq. 6:

$$\lim_{n\to\infty} P\left\{\left|\frac{\mu_n}{n} - p\right| < \varepsilon\right\} = 1 \quad (6)$$

Suppose the mathematical expectation and variance of mutually independent random variables $X_1, X_2, \ldots, X_n \ldots$ exist and there is a constant c such that $D(X_i) \le c(i = 1, 2\ldots)$, then for any $\varepsilon > 0$, it satisfies the Eq. 7:

$$\lim_{n\to\infty} P\left\{\left|\frac{1}{n}\sum_{i=1}^{n} X_i - \frac{1}{n}\sum_{i=1}^{n} E(X_i)\right| < \varepsilon\right\} = 1 \quad (7)$$

Error analysis: According to the central limit theorem, if the random variable sequence $X_1, X_2, \ldots, X_n \ldots$ is independently distributed and it has a finite non-zero variance δ^2, as described in Eq. 8 below:

$$0 \ne \delta^2 = \int (x - E(X))^2 f(x)\,dx < \infty \quad (8)$$

Then we have Eq. 9:

$$\lim_{n\to\infty} P\left\{\frac{\sqrt{N}}{\delta}\left|\bar{X}_N - E(X)\right| < x\right\} = \frac{1}{\sqrt{2\pi}}\int_{-x}^{x} e^{-\frac{t^2}{2}}dt \quad (9)$$

When the N in Eq. 9 is sufficiently large, there is the approximate formula as in Eq. 10 below:

$$P\left\{\left|\bar{X}_N - E(X)\right| < \frac{Z_\alpha \delta}{\sqrt{N}}\right\} \approx 2\int_0^{Z_\alpha} e^{-\frac{t^2}{2}}dt \quad (10)$$

Equation 10 shows that the order of error convergence rate is $O(1/\sqrt{N})$ and it sets up by the probability 1-α, the error ε of the Monte Carlo method is usually defined as $\varepsilon = Z_\alpha \delta/\sqrt{N}$.

The error of Monte Carlo method is probability error and it is different from other numerical computation methods. Moreover the mean variance in error is unknown, you must use its estimated value $\hat{\delta}$ and the calculation method of the estimated value is shown in Eq. 11:

$$\hat{\delta} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} X_i^2 - \left(\frac{1}{N}\sum_{i=1}^{n} X_i\right)^2} \quad (11)$$

When the confidence level α is given, the error ε is decided by δ and N. Try to reduce error ε through: increase N, decrease variance δ^2, or process both. When the δ is fixed, in order to increase the schedule by a magnitude, the number of tests needs to increase two orders of magnitude. The error of the Monte Carlo method is the probability error, so simply increasing N is not an effective way to improve the accuracy, so reducing the size of the variance meanwhile is equally compelling. The merits of the method to increase the precision of error are mainly determined by variance and the cost to observing a sub-sample. The cost refers to the time to use computer, also the concept of efficiency which is defined as $\delta^2 c$, wherein c represents the average cost to observe a sub-sample.

BASKETBALL HIT RATE SIMULATION

Judgment criterion of hollow ball hit rate: The assumption 5 shows that the shot angle should be up, that is $\beta < \pi/2$. Since the basketball centroid movement in x axial direction and y axial direction is uniform motion, so the deflection angle should satisfy:

$$-\arctan\frac{1}{R-r} < \alpha < \arctan\frac{1}{R-r}$$

So, the criterion 1 is to determine the angle α, β.

When the criteria are met, the basketball will certainly have a rising trend. If the increase height of the basketball centroid cannot reach the height of the basket, it will not appear the hollow ball hit situation. Only when the largest displacement of the centroid in the vertical direction is greater than the height of the basket, as shown in Eq. 12:

$$\frac{1}{2}gt^2 - v_0\cos\beta\cdot t + 3.05 - h = 0 \quad (12)$$

Only when the quadratic Eq. 12 has two real roots can possible appear the case of hollow ball hit which is in the Eq. 12 where $\Delta > 0$.

Substituting the two roots obtained from the Eq. 12 into the Eq. 1 can solve the two coordinates of the sphere center at the two moments, respectively, $(x(t_1), y(t_1), 3.05\text{-}h)$ and $(x(t_2), y(t_2), 3.05\text{-}h)$ and $t_1 < t_2$. Then determine the distance from the two points to the two ring center and define them respectively as d_1, d_2. Only when $d_1 \ge R+r$ and $d_2 \ge R-r$ can it possible to make a goal.

When the situation meets the above three criteria, basketball surface may still result touch the ball basket, so according to the equivalent relation in Eq. 3 obtain Eq. 13:

$$d_{min} = \left(\sqrt{(x(t)-1)^2 + y(t)^2} - R\right)^2 + (z(t) - 3.05 + h)^2 > r \quad (13)$$

So four evaluation criteria are as follows:

Criterion 1: If $\beta < \pi/2$ and:

$$-\arctan\frac{1}{R-r} < \alpha < \arctan\frac{1}{R-r}$$

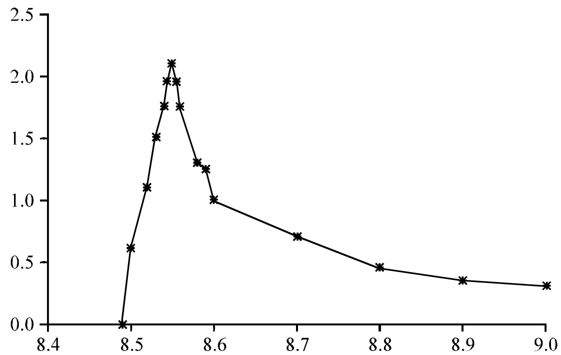

Fig. 2: Scatter diagram of hit rate changing with speed

it meets the judgment of the first step, indicating that there is probably of a successfully hollow shot; you can continue to use the criterion 2 to judge, otherwise stop judgment.

Criterion 2: When Δ>0, it satisfies the judgment of the second step, indicating that there is probably of a successfully hollow shot; you can continue to use the criterion 3 to judge, otherwise stop judgment.

Criterion 3: If $d_1 \geq R+r$ and $d_2 \geq R-r$, it meets the judgment of the third step, indicating that there is probably of a successfully hollow shot; you can continue to use the criterion 4 to judge, otherwise stop judgment;

Criterion 4: When $d_{min}>r$ hollow shooting will be realized, otherwise dissatisfy.

Implementation results analysis of monte carlo algorithm: There are a set of two-dimensional computer-generated random number (α, β) and the number is n. The two-dimensional random array represents the random shooting times in each direction. When the number of the generated random array program-generated is larger, the error caused by fluctuation phenomenon will be smaller. This article select n = 6.0H10^7, the initial condition is defined as l = 6.25 mm. The length is the distance of international standard three-point line, the height h = 2 m is ordinary pitching point height. The program takes the four criteria as constraints and obtained the hit rate changing with the shooting speed and the results are shown in Fig. 2.

In Fig. 2, the abscissa represents the initial velocity rate and its unit is m/s; the vertical axis represents the millionth of hit rate. Figure 2 shows that the maximum hit rate of hollow shooting is 2.1 × 10-4, the current rate is 8.55 m sec^{-1}, the corresponding β angle is in the range of 35.37°~ 43.99°. When β = 39.68° then the allowable error of hollow shooting gets the maximum. When the initial rate is less than 8.47 m sec^{-1}, the hit rate of hollow shooting is 0, so the initial rate of shooting behind the arc should be greater than the value.

CONCLUSION

Monte Carlo algorithm although is also a numerical simulation but different from the calculation method of numerical analysis, the algorithm is an algorithm based on probabilistic; The four evaluation criteria given in the text constrain on the hollow shooting under the assumptions; it is divided into a total of four layers, greatly reducing the computation amount of screening and providing a good model base for the Monte Carlo algorithm implementation; The effect of Monte Carlo algorithm generated according to the law of large numbers is much better through a large number of computer simulations; The best shooting angle is β = 39.68°, the best shooting speed is v_0 = 8.55 m sec^{-1}; This study realized Monte Carlo algorithm by Matlab simulation and studied the hit rate of hollow shooting using the simulation results.

REFERENCES

Avci, E. and D. Avci, 2008. The performance comparison of discrete wavelet neural network and discrete wavelet adaptive network based fuzzy inference system for digital modulation recognition. Expert Syst. Appl., 35: 90-101.

Du, C.X., 2000. Comprehensive evaluation methods of physical fitness, basic techniques, psychological characteristics and training level of male basketball players in hubei colleges and universities. J. Beijing Univ. Phys. Educ., 23: 467-470.

Gao, J., 2007. Numerical-calculation and analysis of basketball-shot probability by Monte-Carlo method. Coll. Phys., 26: 12-15.

Grimaldi, D., S. Rapuano and L. De Vito, 2007. An automatic digital modulation classifier for measurement on telecommunication networks. IEEE Trans. Instrum. Measur., 56: 1711-1720.

Li, M., B. Wei and B. Peng, 2012. Study of shooting hit rate of basketball robot based on normal cloudy model. Comput. Eng., 38: 4-9.

Li, Y.Z., 2004. Influence of mechanics elements on percentage of basketball hits. J. Southwest China Normal Univ. (Nat. Sci.), 29: 300-304.

Liu, P.L., 2011. The probability analysis on shoot baskets type. J. Pingxiang Coll., 28: 1-5.

Wu J. and W.L. Gai, 2003. Discusing the main factors offects the percentage of shots. J. Shaanxi Normal Univ. (Nat. Sci. Edn.), 31: 203-204.

Zhang, B. and Y. Feng, 2013. The special quality evaluation of the triple jump and the differential equation model of long jump mechanics based on gray correlation analysis. Int. J. Applied Math. Stat., 40: 136-143.

Zhu, H.Y. and L. Lei, 2010. Fault diagnosis of node in wireless sensor network based on the interval-numbers rough neural network. Proceedings of the 2nd IEEE International Conference on Information Management and Engineering, April 16-18, 2010, Chengdu, China, pp: 535-538.