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Billiards stroke best position selection counter measurements research based on dynamics

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ABSTRACT

Under the hypothesis of billiards fully elastic collision, apply basic theoretical mechanics principle carrying out analysis of movement law after cue ball colliding object ball and before cue ball collides table side, it gives cue ball movement control equation during this period. Use Matlab simulation analyzing cue ball mass center speed and rotational angular speed influence on its movement trajectory. Then use geometrical method and trigonometric function knowledge structure, it puts forward object ball selection ways in playing aren best table net, through comparing Q_i size relations, it gets conclusions whether stroking waist pocket or stroking bottom pocket. Therefore, after making clear object ball entering net and judging, it researches on cue ball position after it colliding with object ball by physical dynamics and integration method, so that it can successfully set barrier for opponent stroking after ensuring own party potting. It improves billiards movement success rate to large extent.

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KEYWORDS

Billiards;
Best position;
Physical dynamics;
Integral equation.

INTRODUCTION

Billiards is not only a kind of leisure indoors sports activity, but also well favored by people and received people widely attentions; meanwhile, it is also competition event in international professional competition, the Asian Games and other major sporting competition, revealing huge sports charm meanwhile caused influence cannot be ignored. From the perspective of related some documents research, by far, China researches on billiards the sports are just getting started, many theoretical knowledge is not deep enough and no systematical technical level improving method. In billiards, it includes lots of scientific principle. Some researchers adopt basic mechanics principle to implement sports dynamics analysis of billiards cue ball and object ball rotations, and analyzes some movement forms of cue ball after it colliding with object ball, it get some relative guiding conclusions for billiards training[1-3]. But due to results are relative indistinct, and it also exists some problems that need to discuss on final cue ball movement direction and path conclusions. With regard to cue ball movement way laws problems after being impacted by cue, Liu Wen-Rui[3] and other researchers in the article "Billiards mechanics analysis under impulse effecting" relative broadly analyzed some cue ball sports forms after it colliding with object ball; Wang Yun-Ying[4] in the article "Mechanical problems in billiards movement" also systematically analyzed when stroking cue ball different positions and before colliding with object ball by cue effecting, cue ball rotational angular speed and mass center speed relative change laws[5-7].

However with computer popularization and application, after simulation billiards exploitation in game has rapidly development, some researchers have begun to engage in research computer billiards game basic methods introduction[5,6]. Due to network game fast development, billiards enthusiasts have higher and higher requests on simulated billiards game accuracy, it asks higher for researchers, which needs to carry out more deeply and systematically research on billiards movement trajectory. Due to in billiards movement, cue ball positions are very important, cue ball position even is decisive for a frame ball success or failure; because one success position not only can build tricky barrier for opponent potting, but also can fight for power time to attack for them. It gets correct seizing for own party victory. Therefore, on the premise guarantee potting rate, it is very important to carry out detailed, correct theoretical research on movement ways after cue ball colliding with object ball[8,9].

Therefore, on the basis of previous researches theory, through billiards movement basic physical mechanics theory, let billiards enthusiasts can more deeply understand ball movement law. Based on this, the paper researches on which ball net to enter in playing aren for cue ball and object ball and makes positioning, after potting rate ensured, it researches cue ball movement laws after it colliding with object ball on the condition of translation and turning.

BILLIARDS MOVEMENT WAY AND MECHANICS BASIC PRINCIPLE ANALYSIS

Arms strength let cue stroke cue ball, after that it let cue ball change in reflected angle, rotation, separated angle and other directions. In this way, it let billiards on the table suffer different friction forces, active forces, after collision it forms into different movement ways, but these movement state is composed of basic translation and turning.

Billiards can be regarded as even mass sphere; its mass center is its geometric center (ball center). According to theoretical mechanics mass center movement theorem theory, it is clear that billiards suffered external force is reflected by ball center movement ways, because ball each point and mass center movement are the same that form into translation and meet momentum principle requests, which is billiards suffered external force colliding, its joint force impulse is equal to momentum variable, it can get formula (1):

$$\mathbf{F}\cdot\Delta\mathbf{t}=\mathbf{m}(\mathbf{V}_2-\mathbf{V}_1) \qquad (1)$$

But for billiards that suffered joint external force not through ball center, ball each point not only turns around its ball center, but also should make same translation with ball center, from theoretical mechanics theory, it is known that the turning conforms to moment of momentum theorem, ball under external force effecting, its joint force impulsive moment is equal to ball angular momentum changes, it gets formula (2):

$$\mathbf{F}\cdot\mathbf{r}\cdot\Delta\mathbf{t}=\mathbf{I}(\mathbf{w}_2-\mathbf{w}_1)\ \ \mathbf{F}\cdot\Delta\mathbf{t}=\mathbf{m}\mathbf{V} \qquad (2)$$

To simplify movement, assume its initial angular speed and linear speed are zero, the paper defines ϑ as stroke Δv angle here; and assume cue horizontal strokes object ball (all following mentioned are assuming horizontal stroke), impact point and ball center connected line and cue included angle is ϑ and $-90^0\le\vartheta<90^0$. Then (l), (2) change into formula (3), (4):

$$\mathbf{F}\cdot\Delta\mathbf{t}=\mathbf{m}\mathbf{V} \qquad (3)$$

$$\mathbf{F}\cdot\mathbf{R}\cdot\Delta\mathbf{t}\sin\boldsymbol{\theta}=\mathbf{I}\cdot\mathbf{w} \qquad (4)$$

CUE BALL AND OBJECT BALL PLAYING AREN BEST NET SELECTION

Assume billiards and billiards table have no friction force impact, meanwhile it is thought that billiards collisions all are fully elastic collision (restitution coefficient is 1), in this way after two balls colliding, they would move in two ball center connected line direction after colliding moment. As Figure 1 show. In Figure 1, number 1 is stroke ball sphere center initial location; number 2 is object ball sphere center initial location, number 3 and number 4 is sphere center location changes in the moment stroke ball colliding with object ball; in figure $\angle 314=\angle\alpha$ is player stroking normal slip angle, $\angle 324=\angle\theta$ is corresponding object ball angle change after being stroked out.

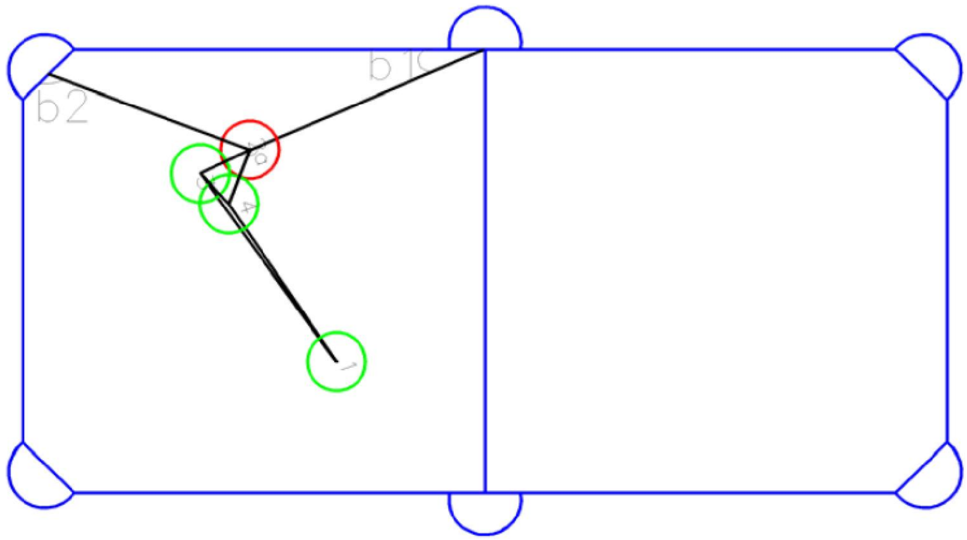

Figure 1: Billiards playing aren best net selection

In $\Delta 123$, assume $\overline{21} = l, \overline{23} = 2\alpha, \angle 213 = \alpha, \angle T21 = \theta, \overline{31} = b,$ therefore it can solve according cosine law: $b = \sqrt{4a^2 + l^2 + 4al\cos\theta}$.

In $\Delta 314$, from sine law, it gets formula (5):

$$\overline{34} / \sin\angle a = \overline{14} / \sin\angle 134 \quad (5)$$

While in isosceles $\Delta 234$, $\angle 234$ approximates to $\pi/2$ so inputs $\angle 134 = \theta - a - \pi/2$ into (5) and considering Δa. It gets minimum, and can get formula (6):

$$\overline{34} = -b / \cos\angle 231 \angle a \quad (6)$$

In isosceles $\Delta 234$, $\Delta\theta$ is minimum, so can get formula (7):

$$\Delta\theta = \overline{34} / 2a \quad (7)$$

Input (6) into (7), it can get: $\Delta\theta = -(b/2a\cos\angle 231)\cdot\Delta a$

For certain object balls and stroke balls, we can select to stroke waist pocket or bottom pocket, therefore after considering the two cases, it can write above formula into formula (8):

$$\Delta\theta_i = -(b / 2a\cos(\angle 231)_i)\cdot\Delta a$$

$$\{(\angle 231)_i \in (\pi/2, \pi))\, i = 1,2\ \} \quad (8)$$

Due to $\Delta\theta$ generated object ball divergence in goalmouth is formula (9):

$$\Delta S_i = -(b_i / 2a\cos(\angle 231)_i)\cdot\Delta a\cdot m_i \quad (9)$$

Meanwhile goal to object ball, its corresponding practical width is $d_i \sin b_i$ (d_i is waist pocket and bottom pocket, 1 is waist pocket, 2 is bottom pocket, b_i as Figure 1 shows). Record formula (10):

$$I_i = d_i \sin b_i - 2a \quad (10)$$

Therefore, it is clear when $I < 0$, ball cannot pot. Then from: $Q_i = -2a(d_i \sin b_i - 2a)\cos(\angle 231)_i / b_i \cdot \Delta a \cdot m_i$ $(i = 1,2)$

According above algorithm, it can get conclusions by comparing comparative coefficient Q_i sizes as well as makes clear it should stroke waist pocket or bottom pocket, therefore, when $Q_1 < Q_2$, player should select to stroke waist pocket. When $Q_1 > Q_2$, player should select to stroke bottom pocket, when $Q_1 = Q_2$, stroke waist pocket or bottom pocket is available. Meanwhile it can also adopt BASIC program more correctly getting best probability which goal should object ball pot, it provides initial correct guiding for athletes stroke selection, bellow provides program flow Figure 2.

TRANSLATION AND TURNING CASES' CUE BALL MOVEMENTS

After learning playing aren ball best net entry position's selection, it starts to research how to stroke and after stroking ball movement status. Establish coordinate axis as Figure 3 show.

v_0 is cue ball mass center speed, defining along x axis positive direction as positive; w_0 is rotational speed that cue ball surrounds its mass center, defining clock-

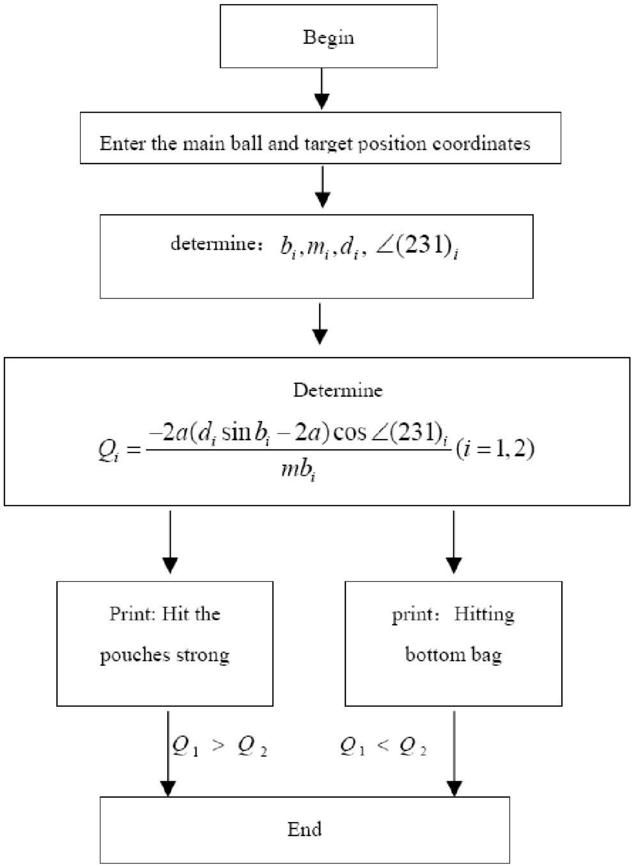

Figure 2 : BASIC program flow chart

wise as positive; f is sliding friction force between cue ball and table, defining along x axis positive direction as positive. Let cue ball radius to be r, mass is m, sliding friction coefficient between table and cue ball is μ, gravity accelerated speed is g. From theoretical me-

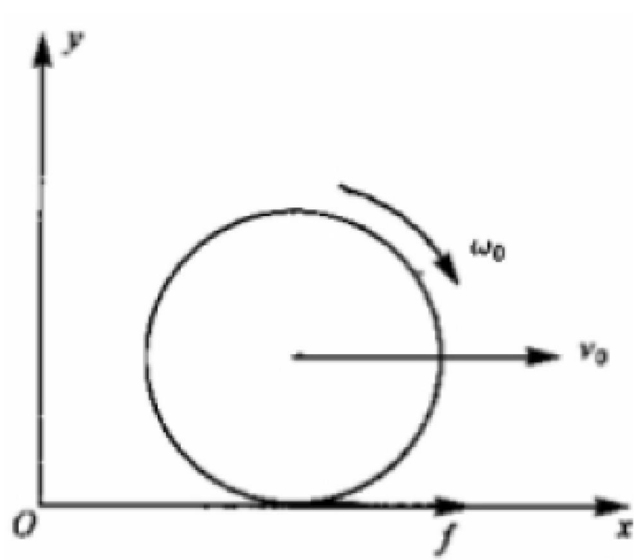

Figure 3 : Cue ball movement analysis

chanics knowledge, it is clear that on the condition $r \cdot w_0 > v_0$, cue ball and table contact point movement direction is x axis negative direction, thus, table effects positive friction force on cue ball, it gets $f = \mu mg$; when $r \cdot w_0 = v_0$, cue ball is pure rolling, at this time, table and cue ball have no friction force; and when $r \cdot w_0 < v_0$, cue ball, it gets $f = \mu mg$; when $r \cdot w_0 = v_0$, cue ball is pure rolling, at this time, table and cue ball have no friction force; and when $r \cdot w_0 < v_0$, cue ball and table contact point movement direction is x axis positive direction, at this time, table effects negative friction force on cue ball, it gets $f = -\mu mg$. Below are respectively carrying out solution on cue ball three movement ways.

When $r \cdot w_0 > v_0$ cue ball motion equation

At this time, positive friction force existing between table and cue ball, cue ball movement way is:

$$\mathbf{f \cdot t = m(v - v_0)} \quad (11)$$

$$\mathbf{-f \cdot r \cdot t = J \cdot (w - w_0)} \quad (12)$$

$$\mathbf{f = \mu mg} \quad (13)$$

From which, v_0 is cue ball mass center instantaneous speed, w_0 is instantaneous rotational angular speed that cue ball surrounds mass center, $j = \frac{2}{5}mr^2$ is cue ball rotational inertia to mass center horizontal.

When $v = w \cdot r$, cue ball starts to make pure rolling, cue ball and table in contact point position have no relative movement tendency, so sliding friction force f is zero, cue ball will stop moving under resistance (ball and table rolling friction resistance and air resistance etc.) effecting after rolling some distance; as for cue ball movement distance from pure rolling to statistic such time phase, it has no great influences on cue ball long distance position, which ignored in the paper. From equation (11), (12), (13) and condition that $v = w \cdot r$, it can solve sliding friction force acting time t_1 as formula (14):

$$\mathbf{t_1 = \frac{2}{7} \cdot \frac{(r \cdot w_0 - v_0)}{\mu_g}} \quad (14)$$

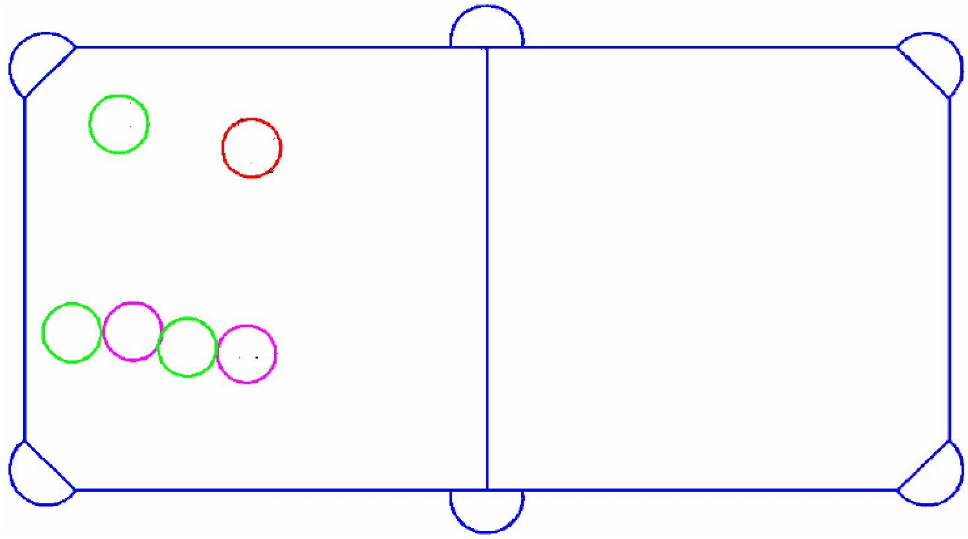

Figure 4 : Cue ball and object ball movement schematic figure

Input (14) into(11), it can solve cue ball pure rolling moment mass center speed v_1 as formula (15):

$$v_1 = \frac{5}{7}v_0 + \frac{2}{7}r \cdot w_0 \quad \textbf{(15)}$$

When time $t < t_1$, from (11) and (13), it can solve formula (16):

$$\mathbf{v = v_0 + \mu_g t} \quad \textbf{(16)}$$

According above conclusions, it gets cue ball displacement as formula (17):

$$s_1 \begin{cases} \int_0^{t_1} vdt = v_0 t + \frac{1}{2}\mu_g t^2 (\mathrm{t} \le t_1) \\ \int_0^{t_1} vdt + \int_{t_1}^{t} v_1 dt = -\frac{2v_0^2}{49\mu_g} + \frac{4v_0 r w_0}{49\mu_g} - \frac{2(rw_0)^2}{49\mu_g} + \left[v_1 = \frac{5}{7}v_0 + \frac{2}{7}r \cdot w_0 \right] (\mathrm{t} > t_1) \end{cases} \quad \textbf{(17)}$$

When $r \cdot w_0 = v_0$ cue ball motion equation

At this time, table and cue ball friction force is zero, cue ball stops moving under resistance (air resistance, rolling friction resistance etc.) effects. Cue ball displacement can be formula (18):

$$\mathbf{s_2 = \int_0^{t_1} vdt = v_0 t} \quad \textbf{(18)}$$

When $r \cdot w_0 < v_0$ cue ball motion equation

At this time, table and cue ball exist positive friction force that is formula (19):

$$\mathbf{f = -\mu mg} \quad \textbf{(19)}$$

When time $t < t_1$, from (11) and (19), it can solve formula (20):

$$\mathbf{v = v_0 - \mu_g t} \quad \textbf{(20)}$$

According to (11), (12), (14), (15), (19), (20) similarly it can solve cue ball motion equation as formula (21):

$$s_1 \begin{cases} \int_0^{t_1} vdt = v_0 t + \frac{1}{2}\mu_g t^2 (\mathrm{t} \le \mathrm{t}_1) \\ \int_0^{t_1} vdt + \int_{t_1}^{t} v_1 dt = -\frac{2v_0^2}{49\mu_g} + \frac{4v_0 r w_0}{49\mu_g} + \frac{2(rw_0)^2}{49\mu_g} + \left[v_1 = \frac{5}{7}v_0 + \frac{2}{7}r \cdot w_0 \right] (\mathrm{t} > \mathrm{t}_1) \end{cases} \quad \textbf{(21)}$$

From above equation, it can get conclusions that cue ball movement distance will decrease with sliding friction coefficient μ increasing, and it increases with mass center initial speed increasing. Meanwhile it can solve ball movement journey to define how large force should be used and how larger translational and rotational speed would be generated to better positioning cue ball and object ball. Therefore, select proper position plays certain reference roles in designing snooker for opponent.

In Figure 3, 1 is cue ball, 2 is own party object ball, 304 are opponents balls on call. When cue ball strokes No.2 object ball into waist pocket, the cue ball can rebound into one of 3 left side or right side two locations, so that blocks No.3 ball and No.4 ball let them cannot smoothly pot into net. It gains time for own party, largely increasing winning probability. But meanwhile it requires athletes with good coordination, seizing ability on strength, so under theoretical basis guarantee, it also needs athletes themselves strengthen training so as to increase overall adjusting ability.

CONCLUSIONS

The paper at first assumes that cue ball and object ball make elastic collision, then researches cue ball and object ball playing aren best net selection; it provides BASIC language programming deduction results into computer for calculation. In this way it only needs to input cue ball and object ball position coordinates, then computer will show stroke which pocket is more helpful. Therefore in training, added computer guiding stroke, it can cultivate athletes' sphere sense, improve their stroking accuracy rate. This paper also carries out dynamics theoretical analysis of movement trajectory after cue ball colliding object ball, similarly it can make use of Matlab researching cue ball mass center speed and rotational angular speed influences on cue ball motion trajectory, it gets following conclusions: (1) If cue ball doesn't collide table side, without considering left rotation or right rotation influences on cue ball motion trajectory, therefore the paper provides cue ball control equation that can define cue ball motion trajectory after colliding. (2) After cue ball and object ball colliding, mass center speed and rotational angular speed have great influences on its trajectory, which the bigger mass center speed is, the smaller rotational angular speed is, and then cue ball trajectory will get closer to cue ball and object ball common tangent.

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