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Baseball game pitcher knocks out batter best model and strategy research

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ABSTRACT

In baseball game, the most important linkage is fighting between pitcher and batter. Pitcher as field defense player with strongest offensive, it plays a decisive roles in restricting batting party attack. Pitching qualities can affect and control attack party players' batting quality, and further affect whole game result. Pitching technique and strategy play a key role, it decides whole game. This paper according to major league baseball and Korean baseball organization's partial statistical information, by analyzing pitching techniques as well as pitcher and batter measures situation table, use judging expectation value method to calculate best pitching method that pitcher knocks out batter. Result shows that best strategy for pitcher restraining batter batting is that select pitching mostly in upper area that no pitching on middle area, every 10 times pitching, choose to pitch toward upper area for 4 times and pitch toward lower area for 6 times.

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KEYWORDS

Baseball pitcher;
Pitching technique;
Batter;
Expectation value;
Strategy theory.

INTRODUCTION

Modern baseball is derived from British cricket and created in America. In 1839, American Doubleday organized the first match baseball game which was quite similar to modern baseball, it proceed between Boston team and New York team. In 1945, baseball historically first competition rules came, which was uniformly named by American Cartwright. And it defined baseball such title, many clauses in the first rules has been continued using until now. In baseball game, defense party's pitcher stands in the midpoint of infield, attack party's batter stands in the batting field, the two forms game direct confrontation. The pitcher is people direct controlling batter and base-runner, he and catcher (posterior batting area first catcher) compose of defense

party first line of defense. In a game, if pitcher pitching efficiency is good, let batter cannot normally batting, then attack party cannot break through defense party first lane of defense, so that it also achieve protection of the second line and third line of defense.

A completely baseball game will carry out 9 innings game, pitcher in his own defense innings, only accumulate knocking out attack party three players, which immediately declare such inning game is over. Therefore, in a completely game, pitcher at least should take challenge from 27 batters. Assume that every player bats fair fly ball and is legally caught by defense party players till knocking out, pitcher should carry out 27 times pitching ;assume that pitcher pitches three strikes to every batter, and make "strike out" to batters, then the pitcher needs to carry out 81 times' pitching. In real

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baseball game, it is difficult to make hypothesis come true. But one pitcher ends a completely game with less pitching times, and then it will indicate the pitcher's high control rate and high pitching level. Any pitching tactics are starting from pitcher ball holding way. Therefore, basis for pitcher developing pitching tactics is how to master holding tactics and main points. Straight shot grip and curve grip is by far pitching mainstream grip. In game, athlete should flexible master ball tactics so as to get winning advantage: one is according to pitch point changes to transform ball grip. That is to use curve ball pitching strike zone middle partial inside partial outside; use rise ball pitching high interior angle and high exterior angle; use drop ball pitching low interior angle and low exterior angle; use floater pitching waist nearby ball. Second is defining grip according to pitching speed, free shots at different speeds, and alternates speed. Third is changing ball grip according to ball changes. When base-runners are on base, equipped ball should helpful to control player, break bunting tactics. Fourth is deciding ball grip according to tactics demands. When tactics required batting high fly ball, it can also equip with rise ball.

To effective restrain batter's ability playing, it required to implement straight fast ball, because its ball speed is fast, it is easier to control sphere, if flexible collocate with pitching point tactics (especially is two low balls, high fork ball), it has much better efficiency. In pitching techniques, fixed ball releasing position is the key of them, when releasing the ball, keep it in the front top of right forehead, and persist every time releasing position should be basically fixed, not changing randomly. When ball is released, put index finger and middle finger on ball top half, and press it hard, let ball produces fiercely rotational speed, meanwhile further increase ball accelerated speed and acceleration capability. At the same time, wrists should cooperate with fingers and make relative actions, if wrists turning angles changes, then fingers' pressing is at ease while it also should change accordingly.

GAMING MODEL ESTABLISHMENT AND SOLUTION

Pitcher can adopt wind-up position and set position two postures, before two kinds of pitching all need

to use foot to pedal pitcher's plate. Wind-up position only allow pitching to batter, after pitching motion starting, motion should continue and not stop. Set position can pass pickoff to base-runners base, but after pitching starting, it only allows to pitch to batter. Before pitching, it should keep static holding, postures in front of body should be at least 1 second. After pitching, baseball height that is below batter hand and shoulder while above knees, while width is inside home plate, such balls all be regarded as strikes. Pitcher accumulates pitching three strikes to batters that knocks out batters. When pitchers pitched baseball is batted in foul territory, which is also regarded pitcher pitching strikes. If batters bat fair fly ball, which is legally caught by any defense party players, it is also regarded as batters are knocked out.

Pitching technical analysis

Key to pitching is ball speed, ball type, control and physical ability. Here it puts emphasis on researching ball types. Baseball sports process in the air involves Bernoulli's principle and fluid mechanical knowledge. Baseball, after being pitched by pitcher, it occurs relative movement with air; therefore, baseball will take air resistance effects, as Figure 1 show.

Baseball almost happens to make rotation, meanwhile baseball marching route will change with pressure, air flow changing, it occasionally swings, and the ball becomes a knuckleball.

When pitchers pitch baseball, middle finger and index finger generate fluctuation on baseball, baseball produces rotation after being out of pitchers, according to different rotation, it will generate breaking balls as upper floater, drop ball, changup, cut, sinker and curve ball. Upper floater ball route is easier to judge, there-

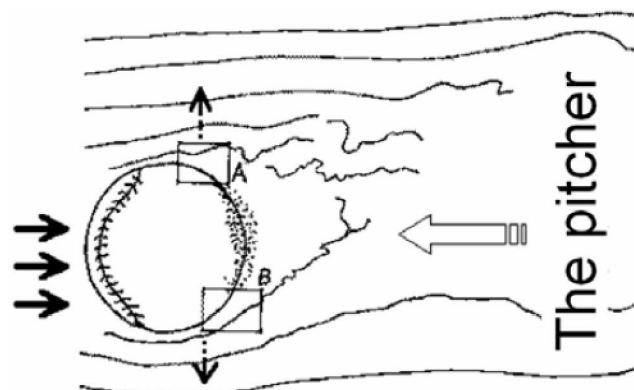


Figure 1: Baseball with air resistance

fore batter easily bats upper floater. Speed up upper floater ball speed, batter batted upper floater is easier to occur high fly ball, at this time; it is convenient for defense player direct catching and knocks out batter. Drop ball and sinker in batting process, it easier happens to ground ball in the second and third infield, when first base has base runners, it is helpful to make double playing.

Pitching strategy

Assume in case pitching strikes, pitcher can fully control baseball well; let baseball to be pitched to any effective batting area. We divide effective batting areas into three parts that are respectively upper area, middle area and lower area, which are pitcher available optional three pitching strategy areas.

According to major league baseball and Korean baseball organization data statistics, two associations' active professional players' player batting index can be written into TABLE 1:

TABLE 1 : American and Korean Players' batting index

Upper area	Middle area	Lower area
0.30	0.38	0.20

Meaning of the index is: For ball pitched to upper area, batters' 10 times batting can play 3 times home runs or base hits. The problem is that pitching generally has no rules, if batter supposed pitching not conform to pitcher practical pitching status, then batters' batting rate would slightly reduce; assume when batter suppose that pitcher will pitch to upper area, batter index would change as TABLE 2:

TABLE 2 : Upper Pitching batter index

Upper area	Middle area	Lower area
0.42	0.25	0

While also assume that batter supposes that pitcher will pitch lower area, batter index changes as TABLE 3:

So, to the batter, there are three incoming ball supposing strategies: upper area, middle area and lower area. Then we get pitcher and batter game situation as

TABLE 3 : Lower pitching batter index

Upper area	Middle area	Lower area
0	0.30	0.40

TABLE 4:

TABLE 4 : Pitcher and batter game situation index

		Pitcher		
		Upper area	Middle area	Lower area
Batter	Upper area	0.42	0.25	0
	Middle area	0.30	0.38	0.20
	Lower area	0	0.30	0.40

From TABLE 4, we are clear that it is a zero-sum game. In practical game, pitcher and batter strategies selection is completely at random, so, this paper will find out best mixed strategy for pitcher.

Zero-sum game

Zero-sum game is a kind of special game problem. In the kind of game, only two insiders, every insider only has finite strategies to select. Under anyone situation, two insiders' winning sum always equal to zero that two parties profits are intensive confronted.

Game problems include many kinds; zero-sum game is very special one of them. In zero-sum game, only set two insiders, and every insider optional strategies are finite. And in any one pure situation, two insiders winning sum is constant to zero that two parties profits have intensive confrontation feature.

Set insider I, II strategy sets are respectively as :

$$S_1 = \{\alpha_1, \alpha_2, \dots, \alpha_m\}, S_2 = \{\beta_1, \beta_2, \dots, \beta_n\}$$

When insider I selects strategy α_i and insider II selects strategy β_j , it forms into a situation (α_i, β_j) , it is clear that such situation has $m \cdot n$ pieces. To any one situation (α_i, β_j) , record insider I winning value s a_{ij} , and call:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}$$

That is insider I winning matrix (or is insider II payoff matrix). Due to assume game is zero-sum, insider II winning matrix is $-A$.

When insider I, II and strategy set S_1, S_2 as well

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as insiderI winning matrix A are defined, a zero-sum game is given, zero-sum game can also be called as matrix game and can simply be recorded as:

$$G = \{S_1, S_2; A\}$$

Given insiderI use probability x_i selecting strategy α_i , insiderII uses probability, y_j selects strategy β_j , $\sum_{i=1}^m x_i = \sum_{j=1}^n y_j = 1$,

Record $x = (x_1, \dots, x_m)^T$, $y = (y_1, \dots, y_n)^T$, then insider I expectation winning is $E(x, y) = x^T Ay$

Record S_1^* :

Strategy	$\alpha_1, \dots, \alpha_m$
Probability	x_1, \dots, x_m

S_2^* :

Strategy	β_1, \dots, β_n
Probability	y_1, \dots, y_n

Respectively call S_1^* and S_2^* are insider I and II mixed strategy.

According to relative definition: if it exists m dimensions probability vector \bar{x} and n dimensions probability vector \bar{y} , let all m dimensions probability vector and dimensions probability vector \bar{x} and n dimensions probability vector \bar{y} have:

$$\bar{x}^T A \bar{y} = \max_x x^T A \bar{y} = \min_y \bar{x}^T A y$$

, then it called (\bar{x}, \bar{y}) is mixed strategy game problems' saddle point.

Zero-sum game linear programming solution

When $m > 2$ and $n > 2$, generally adopt linear programming method to solve zero-sum game problems. The purpose that insiderI selects mixed strategy \bar{x} is to let:

$$\begin{aligned} \bar{x}^T A \bar{y} &= \max_x \min_y x^T A y = \min_y x^T A (\sum_{j=1}^n y_j e_j) \\ &= \max_x \min_y \sum_{j=1}^n E_j y_j \end{aligned}$$

Among them, e_j is vector that only the j component is 1 and other components all are zero, $E_j = x^T A e_j$.

Record $\mu \equiv E_k = \min_j E_j$, due

$$\text{to } \sum_{j=1}^n y_j = 1, \min_y \sum_{j=1}^n E_j y_j, \text{ when } y_k = 1,$$

$y_i = 0 (j \neq k)$, it arrives at minimum μ , so \bar{x} should be linear programming problem:

$$\begin{aligned} &\max \mu \\ &s.t. \begin{cases} \sum_{i=1}^n a_{ij} x_i \geq \mu, j = 1, 2, \dots, n (\text{That } E_j \geq E_k) \\ \sum_{i=1}^m x_i = 1 \\ x_i \geq 0, i = 1, 2, \dots, m \end{cases} \end{aligned} \quad \text{solution.}$$

Similarly, \bar{y} should be linear programming

$$\begin{aligned} &\max v \\ &\text{mining: } \begin{cases} \sum_{j=1}^n a_{ij} y_j \leq \mu, i = 1, 2, \dots, n \\ \sum_{j=1}^n y_j = 1 \\ y_i \geq 0, j = 1, 2, \dots, n \end{cases} \end{aligned} \quad \text{solutions. By linear programming knowledge, it is clear above two formulas are dual programming to each other; they have same optimal objective function value.}$$

ear programming knowledge, it is clear above two formulas are dual programming to each other; they have same optimal objective function value.

Analyzing TABLE 4, it is clear that pitcher adopts pitching in middle area, no matter batter adopts which kind of strategy, and it is possible to hit the baseball. Therefore pitcher to avoid pitched baseball hit, he cannot adopt middle area pitching strategy. Then change TABLE 4 into one 3×2 game table as TABLE 5 show.

Calculate pitcher optimal mixed game

Given pitcher selects a mixed game $(y, 0, 1 - y)$.

TABLE 5: 3 × 2 game table

		Pitcher	
		Upper area	Lower area
Batter	Upper area	0.42	0
	Middle area	0.30	0.20
	Lower area	0	0.40

Select graphical method working out best game corresponding y value. In (y, E) plane straight line $y = 0$ fixed heights are respectively 0.42, 0.25 and 0 point A, B as well as C ; in straight line $y = 1$ fixed heights are respectively 0.40, 0.30 and 0 point A', B' as well as C' . Connect point A and point C' , point B and point B' as well as point C and point A' , and then it gets three straight lines AC', BB' as well as CA' (as Figure 3), their equations are respectively:

$$AC': E + (0.42)y = 0.42 \tag{1}$$

$$BB': E - (0.10)y = 0.25 \tag{2}$$

$$CA': E - (0.42)y = 0 \tag{3}$$

From above 3 equations, it is clear that E value from them is just relative to pitcher mixed game $(y, 0, 1 - y)$, batter 3 kinds of incoming ball supposing strategy corresponding expected values. The 3 straight lines constructed extremely large broken line is $ASPA'$, according to graphic method, its lowest point S should be solution to our problems. Now from Figure 3, it is clear that point S is straight line AC' and straight line BB' intersection point, simultaneous equation (1) and (2), it can solve it. Solve above two equa-

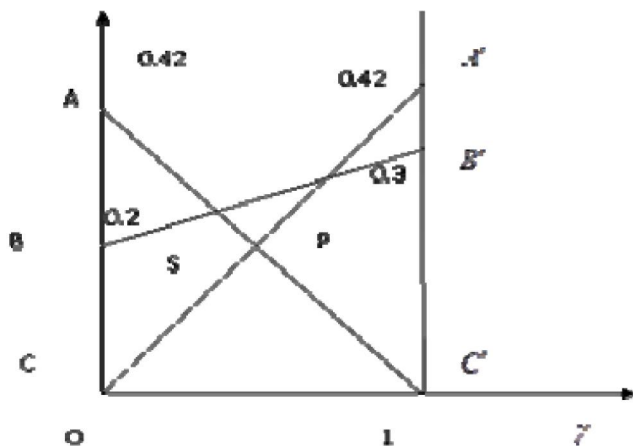


Figure 3 : Graphic method calculating

tions, and then it can get optimal solution $(y, E) = (0.42, 0.22)$.

CONCLUSIONS

According to above calculation result, it is clear : pitcher best strategy to restrain batter batting is selecting to more use upper area to pitching and not pitch middle area, every 10 times pitching, select pitching to upper area for 4 times, pitching to lower area for 6 times. Meanwhile it makes suggestions to pitcher as following:

Pitching strategy

Pitcher should consider using upper floater pitching more. Drop ball and sinker utilization meet batting strategy “4 upper 6 lower” pitching proportion, it is easily to achieve batter swing bat in vain. Meanwhile, if batter bats with success, drop ball and sinker would more easily appear infield ground ball, which is convenient to defense player to catch and run down base-runner.

Cooperate with catcher

The catcher gets close to batter, batter’s stance, posture, technical features, psychological weakness, ball selection status, trial adopting attack tactics and field situations as well as others are open-and-shut, it is easily to find out batter’s disadvantages.

Pitching pickoff

Pitcher’s pickoff status only happens when there is someone on the base. Main task is picking off base-runners’ off-base distance, the next is picking off base-runners who leave too soon.

Cover consciousness in participating run down

No matter which base has runners, when succeeds in picking off, it may happens to run down, at this time pitcher should make clear about cover direction that when picking off first base runners and generating run down, it should cover first base; in case pickoff second base runners and generate run down, it should cover the third base; in case pickoff third base runners and generate run down, it should cover home base.

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