



Tennis tournament techniques and tactics performance influence factors and strategy research based on game theory

Jianguo Liu

School of Physical Education and Science, Qufu Normal University, Qufu, Shandong, China

ABSTRACT

Utilize game theory relative principles and content methods to carry out analysis and discussion on tennis tournament tactics implementation, including tactical consciousness, combination, action and other processes. Research finds game strategy principle that tennis player should apply is giving play to its strong points and avoiding its shortcomings, positively utilizing dominant strategy, avoiding dominated strategy. Path dependence problems exist in tennis tournament tactics application process, it is also one of the great factors that affects tournament victory or failure; Tennis players should choose correct mixed strategy so as to break through their path dependence problems.

Key words: Game theory, tennis tactics, dominant strategy, path dependence

INTRODUCTION

Chinese tennis development is urgently in need of improving players' tactical abilities. From competitive performance perspective, in the aspect of women, Li Na since achieved career first great slam in Roland Garros in 2011, its performance always in the top level; Zheng Jie, Peng Shuai and others also have shining points in tournament, which indicates that our country women tennis has made new progress and overall level has greatly been improved [1-5]. While men players always haven't entered into world ranking 100, it can be thought that our country still is in the backwards position on men event. Tennis competitive level developed until now, how to continue to improve has already formed into a systematical project, one important path from them is improving tactical training level [6-8].

Foreign research regarding tennis tactics is relative comprehensive, involved in different courts tactics, different playing tactics, different tournament situations tactics. CraigTiley mentioned that just as some scientific principles have same relationships with science and technology, tennis also has lots of basic principles that exist according to its techniques and tactics requirements. ①Well playing success rate; ②acquaint court area; ③make clear objective areas; ④set more limitations on routes changes; ⑤mid-court ball; ⑥attack opponent served shallow ball; ⑦apply 1-2 times continuous hitting; ⑧defense, stalemate, attack; ⑨lock a line; ⑩convert 'transmission'. The book 'Tennis Drill book' put forward scoring ways should be diversified, let opponents always in multiple preparation states, techniques and tactics add mutability so that opponents could not adapt to its tactical styles [2-5].

Since 1990s, with game theory and modern economics have gradually been combined into one, becomes parts of mainstream economics. It has achieved plentiful results and widely application in politics, economic, sociology as well as military, law and other many fields, becomes great 'revolutionary' juxtaposed with 'margin analysis' and 'Keynesian revolution' In economics intellectual history, it brings human race a kind of brand new methodology and thinking [6-8]. In 1994, American famous mathematical talent John Nash, due to he made pioneering contribution in non-cooperative game balance analytical theory aspect, it has great influences on game theory production, gains Nobel economical prizes in that year. In 'Sports game theory', Li Yi-Qun, Xie Ya-Long systematically explored

competitive sports game theory basic concepts, research objects, research contents and research significance, enriched competitive sports game theory's theory system, built firm foundation for sports game theory development, it provided reference directions for guiding competition practical activity.

GAME THEORY

Game theory is also called theory of games, competition theory and strategy theory. It is a theory researching benefit connected (including benefit conflict) main body people's game, is a theory analyzing people rational behavior selection in game, is a theory discussing people how to make decisions in game interactions.

Under game theory basic theory, to completely express a game, it should explain three basic elements player, strategy and payoff. Player generally refers to individual or organization that independent making decisions, independent endure game results in game. Strategy refers when each player that participates in game makes decisions, optional method, practice or economic activities levels, measurement and so on. Payoff refers each player gained benefit from game; it reflects each game participating player pursuit that is also their behaviors and decisions-making main basis. According to whether participating people make simultaneous decisions or not, game is divided into static game and dynamic game, participating people simultaneous decision making game is called static game, participating people not simultaneous decision making is called dynamic game. According to whether each participating people all know all participating people gain and loss in each game, it divided into complete information game and incomplete information game, the game that every participating people knows all participating people gain and loss in each game is called complete game, the game that at least one participating person don't know one of participating people gain and loss in one game is called incomplete information game, therefore, standard game theory normally including complete information static game, complete information dynamic game, incomplete information static game, incomplete information dynamic game. According to players quantity in game, it can divide game into 2 people game and n people game, it can also according to each game total payoff features divides game in zero-sum game and non -zero-sum game [9].

Game definition: Given in one n game, multiple players strategy set as S_1, \dots, S_n , every player payoff as u_1, \dots, u_n , all are functions define in $S_1 \times S_2 \times \dots \times S_n$, we record the game as: $G = \{ S_1, \dots, S_n; u_1, \dots, u_n \}$

In concrete terms, every player i simultaneous choose their strategy $S_i \in S_i$ from respective strategy set, here $i = 1, 2, \dots, n$. After S_1, \dots, S_n all making selections, every player i will get a corresponding payoff u_i . And every payoff function u_i is n pieces of variables S_1, \dots, S_n real function. As Figure 1 show the two people game. Among them, $S_1^1, S_2^1, \dots, S_m^1$ is player 1 all counter measures, $S_1^2, S_2^2, \dots, S_n^2$ is player 2 all counter measures, In square, a_{nm}, b_{nm} respectively representative player 1 payoff to player 2, put a_{nm} payoff on the bottom left of square, put b_{nm} payoff on the upper right of square, as Figure 1.

		player2			
		S_1^2	S_2^2	\dots	S_n^2
player1	S_1^1	b_{11} a_{11}	b_{12} a_{12}	\dots	b_{1n} a_{1n}
	S_2^1	b_{21} a_{21}	b_{22} a_{22}	\dots	b_{2n} a_{2n}
	\cdot	\cdot	\cdot	\cdot	\cdot
	S_m^1	b_{m1} a_{m1}	b_{m2} a_{m2}	\dots	b_{nm} a_{nm}

Figure1: Two people game matrix expression

Nash equilibrium is basic theory in game theory. It is introduced under absolute dominant strategy and relative dominant strategy. Nash equilibrium refers to the game that player single changing strategy cannot get benefit. Nash equilibrium isn't payoff itself but caused payoff strategy combination.

Players apply tactics in court is actually a game, one party players have variety of tactics that can be used, while the

opponent players also have variety of tactics that can be used, two parties each tactic confrontation will lead to different results, and each party hopes to get benefit from it that is a kind of typical game process.

According to above game theory principle, we apply it into tennis tournament tactics selection process. At first, use a、b、c respectively represent player x(player) tactical selection(strategy), use A、B、C、D respectively represent player y tactics selection. '+, -'(payoff) shows player x tactics selection success, '-, +'shows player y tactics selection success, two parties tactics selection success analysis is as Figure 2-2shows, such one permutation matrix is called two people game payoff matrix(payoff matrix), the formed game is called matrix game. In concrete terms, player x adopts some kind of service tactics(as external angle、forward spin and so on)would have several payoff, (gain low quality receive, gain high quality receive, passive receive directly ace and so on)use square bottom left corner '-or+'to express(it can also give concrete values according to corresponding ratios).Player y according that served ball have several receive strategies(pull forward spin overhead, smash straight line ball, smash crosscourt, smash down-the-middle shot and so on), similarly it also has several payoff(ace, fail etc.), use square top right corner '-or+'to express. Therefore, 2 people game result has following 12 types (as Figure 2).

Combine with game theory and tennis tournament features, we think tennis tournament tactics game possess following basic features, it can be regarded as 2 people(team) zero-sum game; decision-making time is quite short; most game is 'Nash equilibrium' game. Therefore, game theory has a certain guiding significance on tennis tactics research.

		player y			
		A	B	C	D
player x	a	+ -	+ -	- +	- +
	b	- +	+ -	+ -	- +
	c	- +	+ -	+ -	- +

Figure 2: Tennis player y, x tactics selection operation figure

TENNIS COMPETITIVE GAME PROCESS

Static game

Static refers to game player simultaneous decision-making or simultaneous-move. Simultaneous decision-making or simultaneous-move concept doesn't mean totally simultaneous and coherent in time, but means before decision making one party of game don't know what decision or move the opponent would adopt. Before tennis team competition starting, participating team that is each game party, players' order of appearance appointment is typical static game problem. Typical game 'Rock-Paper-Scissors' and race Tianji also belong to static game problems.

Dynamic game

If player's decision-making or move according to the rule of sequential-move, and post-selection, move player usually can observe pre-selection, move player's selection and move, which is dynamic game. Tennis tournament process obviously is a kind of dynamic game problem. Each round takes server's service as pre-move, receiver's receive as post-move, in the subsequent alternate continuously confrontation, two parties define their next racket strategy choice through observing opponent court tactics performance till the point ends, tactical move gains success. We set examples to state tennis tactics dynamic game problem. We assume player A has two strategies choice after service, one is keeping the base line and attack opponent, and another is attack-after-service. If choose attack-after-service, player B observes player A such move, then he will choose two strategies, one is playing through, and can also choose high volley, values in bracket represents their payoffs after strategy selection. Among them, the front number represents A payoff, the back represents B payoff. If B hasn't successful through and is successful intercepted by A, then payoff is -1, if choose high volley that gain success, then payoff is 1. As Figure 3 shows. It is a two game parties two phases dynamic game, one of the most basic types in dynamic game.

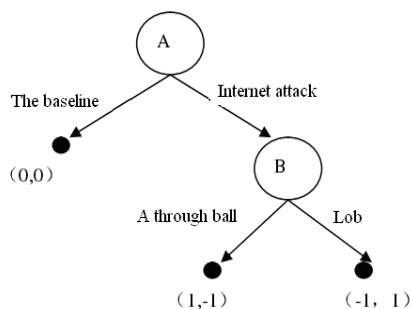


Figure 3: Dynamic game expansion form

Repeated game

Repeated game is a kind of special type game that composed of same structure, many times even infinite times repetition 'phase game'. Because other participants' past move history can be observed, in repeated game, every participant can let its each phase strategy selection depend on other participants past move. In such type game, one game party past decision-making is observable to another game party; therefore each game party subsequent new 'phase game' strategy selection can reference their opponents' past move and make adjustment accordingly.

Tennis tournament obviously is a repeated game. Men four grand slams seasons' best of 5 sets and women four grand slams best of 3 sets; each set has 6 games, in non-average sets it fixes tiebreak, its phase game is each game each point confrontation, such certain game or sets tournament is a repeated game with regulated games or sets as repetition times.

TENNIS TOURNAMENT TACTICS APPLICATION SEQUENTIAL GAME AND DOMINANT STRATEGY, DOMINATED STRATEGY

Sequential game

Tactical move happens in successive that game participants move with sequence and respond in turn; therefore, the game is also called sequential game. In the starting phase of sequential game, one participant established his own initial judgment according to others different types and belonging types probability distribution. In game process, the participant can revise his initial judgment according to others actual move that he observed, and judge select his strategies according to such constant changes.

First-move advantage

Sequential game has one important feature that is one game party would always first move. It is naturally, second will appear when there is a first one; in sequential game, there is always one game party would move followed by others. For two people sequential game, it must and only have one first mover, similarly have one second mover. Two participants, if it is not first mover then it would be the second one, one first moves, one second moves. Any party first moves payoff that might obtain is larger than that from second mover, such game party first move payoff better than second mover situation is called first-move advantage. First-move advantage can be reflected in tennis tournament service. For adversaries of comparable strength, first service has a psychological advantage in final set especially in average set; first service is easier to dominant in score, the backward party has greater psychological stress.

Second-move advantage

In daily life, we usually put forward saying of 'the best defense is offense', lots of examples indicate that in some games, it tends to be that first move first decision making party will gain extra advantages, but there is no proposition or theorem proves that first move party will always get payoffs. In fact, there are some sequential games, some of which the second move party payoff is larger than their first move party one. Such second move payoff is larger than first move one situation is called second-move advantage.

Through making statistics of world professional tennis players competition scores, it is clear that men professional players' score ways rank in successive according to top three proportions as opponent fault accounts for 38.38%, service 22.36%, winner 20.11%; women professional players' score ways rank in successive according to top three proportions as opponent fault accounts for 45.84%, winner 27.50%, service 15.85%. The statistics result shows tennis tournament winning not mainly relies on first strike's imitiveness. In one tournament, as fighting opponents two parties, it is impossible that both two will not make mistakes, one high level high intensity antagonistic tournament, it is usually seen that tournament two parties long time base line multiple rackets seesaw, result tends to be that first initiative line changing party will appear faults, second move party in waiting process, 'wait' opponent makes

mistakes, seizes combat opportunity and gains success.

To sum up, in tennis tournament practical game, it has first move dominant strategy and also second move dominant strategy. Since situations are unexpected in competition court, if one party sticks to convention, it will only make itself let slip a golden opportunity. Therefore, real game master absolutely is master of rupturing opportunity, he will flexible choose first move or second move according to participant each party concrete situation changes.

Roll back, backward induction

Roll back backward induction, it is facing to future, thinking about present, defining present optimal move on the stance of future. That is to say, outlook what result that your initial decision finally will lead to, make use of such information to define your best choice. In tactical move successive occurred sequential game, participating competitive game two parties players have to prospect forward, before adopting tactical move, they should estimate opponents reactions so that deduce backwards so as to decide what they should do in the round. It is a linear deduction chain 'If I do this way, my opponent will do that way, if so, I'll fight back this way...'. Make analogy from this. We make use of 'tree diagram' as visual as assistant tool to apply roll back backward induction here, make deduction on game process decisions selecting.

Tournament cases (to easier state problems, ignoring tournament process uncontrollable factors): In 2009 Australian Open Tennis Championship Men singles final, Nadal verse Federer, big set score 2:2, final set score 5:2, the 8 game Nadal40:15 gripped two sets and are match points, Federer served in right court.

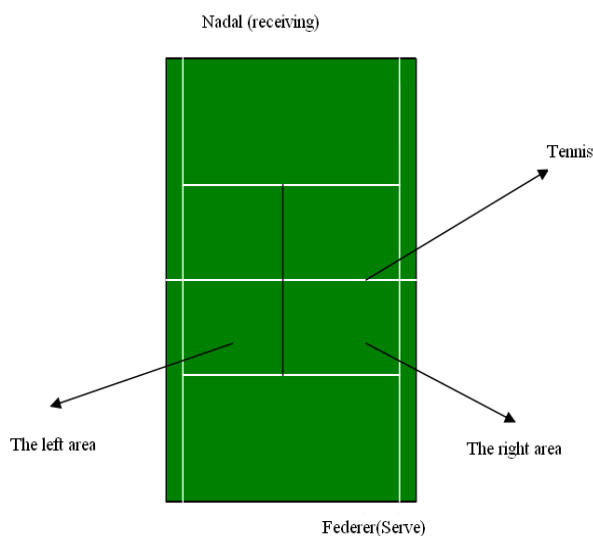


Figure 4: Tennis court

We analyze the sequential game from it:

- Game two parties: Federer, Nadal;
- Strategy space: Federer optional move is 'external angle service' or 'inner angel service', Nadal choice is 'receive linear ball' or 'receive crosscourt';
- Action order: Federer serves, Nadal 'observed' Federer actions then choose his actions;

Two parties payoffs:

- A If Federer serves 'outside pitch', Nadal chooses 'receives linear ball', then, no matter what Nadal returning quality is, it cannot directly lose the point but enter into next phase game, record everyone gets score 0;
- B If Federer serves 'outside pitch', Nadal chooses 'receives crosscourt', and then, due to Federer outshoot service has greater advantages, Nadal backhand returns crosscourt quality is surely lower, Federer the third racket utilizes forehand attacking, Federer gains 1 score, Nadal losses 1 score;
- C If Federer serves 'inside pitch', Nadal chooses 'receives linear ball', and then he will make use of his relative stronger forehand through straight line attacking Federer relative weaker backhand so that set up advantages for next racket, here Nadal gains 1 score, Federer losses 1 score.
- D If Federer serves 'inside pitch', Nadal chooses 'receives crosscourt', at this time Federer can set up advantages by forehand straight line shooting, here record Federer gains 1 score, Nadal losses 1 score; the game can use 'tree diagram' to express as following:

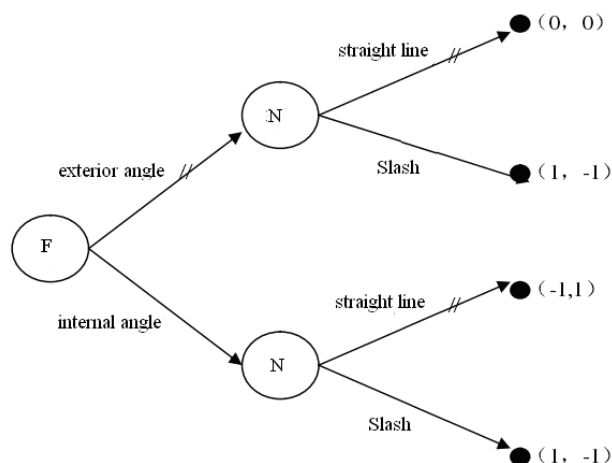


Figure 5: Federer and Nadal service and receive game expansion form

Figure 5 interpretation as following: Federer chooses to serve ‘inside pitch’ and ‘outside pitch’, Nadal chooses ‘receive straight line shoot’ and ‘crosscourt shoot’, rightmost bracket numbers represent different situations two parties payoff situations, from which left numbers represent Federer payoff, right ones represent Nadal payoff.

Inverse method backward induction steps are as following:

At first, it starts considering from last phase move game people decision-making, in above figure, final move people is Nadal, then we first consider Nadal decision-making. When considering his decision-making, we assume that Federer has already chosen serving inside pitch and outside pitch two strategies, if Federer chooses serving outside pitch, Nadal chooses receiving straight line will get 0, while chooses receiving crosscourt will get -1, Nadal surely will choose receiving straight line –We draw short double horizontal lines as marking in Nadal choosing receiving straight line branch.

If Federer chooses serving inside pitch, Nadal chooses receiving straight line shoot will get 1, receiving crosscourt shoot will get -1, and we draw short double horizontal lines as marking in Nadal choosing receiving straight line branch.

Then consider such phase move game party Federer. When Federer makes decisions, he will consider Nadal reactions, now he already predicts Nadal action plan is two branches drawing double horizontal lines. Accordingly, he can deduce the status he would face is:

- If choose to serve inside pitch, it surely lead to Nadal receiving straight line, Federer gets -1;
- If choose to serve outside pitch, then, when Nadal chooses receiving crosscourt, then Federer gets 1; when Nadal chooses receiving straight line, then Federer gets 0;

Result is Federer prefer to choose serving outside pitch. According to the rules, we make double horizontal line marks in Federer serving outside pitch branch; If it exists one path, its every branch drawn double horizontal lines, then the path is balance path. It can be found, in Figure 5 example; balance path would be Federer choosing ‘outside pitch service’, and Nadal chooses ‘receiving straight line shoot’, enter into next phase game process. Therefore, Federer and Nadal such service game balance result is that Federer chooses serving outside pitch and Nadal chooses receiving straight line shoot.

In actual tournament, Federer chose serving outside pitch, while Nadal chose receiving crosscourt; finally Federer got such one point. Here, it is important for us to master forward prospecting, backward induction roll back backward induction. If Nadal was more computational at that time, and also mastered ‘forward prospect, backward induction’ roll back backward induction, he would adopt backhand receiving straight line shoot and entered to next phase game process, in that way perhaps he might could convert passive into initiative directly win the tournament. When doing theoretical researching, we make use of ‘forward prospect, backward induction’ roll back backward induction solving the game balance solution—that is finding out the balance path, while in actual tournament, we should consider the situation, make flexible application.

If our party player dominants, it should do exactly the opposite –that is breaking through the balance, winning one

round, one game or even one tournament; if our party player is relative passive, it should initiative to look for the balance, first transit to stalemate, and then seize the opportunity to fight back.

Dominant strategy and dominated strategy

In two people game, if game party A has a strategy, then no matter what the other game party B will do, the strategy will be more skillful, then A has a dominant strategy. Game theory will state that if you have a dominant strategy, please follow it. Ignoring what your opponent will do; similarly, if A adopts one strategy, no matter what strategy B will adopt, A such strategy will be slightly inferior, then such strategy of A is dominated strategy; a dominant strategy is better than any other strategies, similarly, a dominated strategy is inferior to any other strategies. If you have a dominated strategy, please follow the principle ‘eliminate dominated strategy, without considering’. We explain game’s dominant strategy and dominated strategy problems with following examples.

Tournament scene: In one tournament, A1 location player A and B1 location player are in stroking sustained phase on base line. In order to drive opponent so as to fight for time and space initiative, A can choose strategy ‘slash the ball deep’ and ‘fast short oblique deep ball’ to gain time and space.

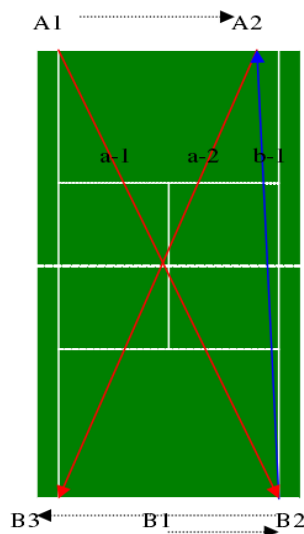


Figure 6: Game route

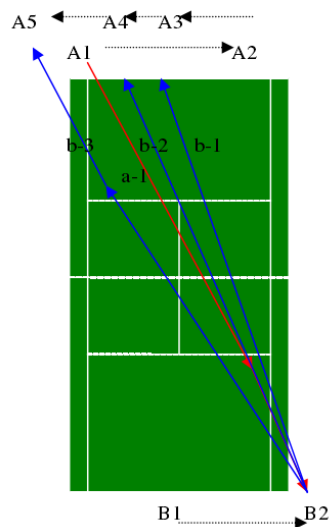


Figure7: Game route

As Figure 6 shows, when he chooses to stroke ‘slash the ball deep’(a-1) from A1, if B can make pre-judgment on court situation will move 4-4.5 meter distance from B1 location to bisection B2 to return . If B chooses to stroke linear deep ball from B2 location (b-1), ball flying time is roughly 1.2 seconds, A makes pre-judgment on B such route returning, through 4-5 meters shifting distance, A moves to location A2, at this time, if stroke slash the ball deep (a-2) from current location to B precedence area B3 location, B needs to move 8-8.5 meters around distance. If A such drop point is correct and fast, B would be quite passive, we respectively record A, B payoff as (1, -1).

Similarly, in Figure 7, if A strokes ‘short oblique deep ball’(a-1), B moves from location B1 to bisection B2, if he chooses to stroke linear deep ball(b-1), what would happen? Choose such strategy, B not only need to move quite a long phase distance, but also stroke outside the double side line, in that way it’s quite passive. B stroked linear deep ball is flying from outside court to inside court, A only needs to move shorter distance so that can arrive at A2 contact point, stroke crosscourt shoot(a-2) from location A2 to precedence area location B3 can let opponent move as long as more than 10 meters distance, that is to say after B stroking straight deep shoot (b-1) in location B2, it is equal to make room for A one quite large neutral position, he himself similarly will lose space and time conditions, we record A, B payoff as (1, -1).

So after A choosing such two strategies, B eliminates ‘linear deep ball’ such one dominated strategy, how to do can get rid of dilemma? We can find answers in Figure 7. One, B can choose to stroke towards A base line center (b-1), A will move to location A3, in this way, A return angle is restricted, B can more effective defense neutral position, we record their payoff here as (0, 0). Two, B can choose to stroke ‘slash the ball deep’ (b-2) strategy, A moves to A4, in this way, B can oppress A to move outside the base line. Three, B can also choose to stroke short oblique deep ball, A will move to location A5. So that B forced A moving to outside court, A left B quite big neutral position. We record A, B payoff as (-1, 1).Game situation:

Game party: player A, player B

Game order: Player A seeks initiatives through changing route; player B adopts corresponding stroke strategy by observing A changes.

Strategy space: A chooses 'slash the ball deep' and 'fast short oblique deep ball'; B chooses 'linear deep ball', 'the deep ball', 'slash the ball deep', 'short oblique deep ball'.

Two parties' payoff:

- A chooses stroking 'slash the ball deep', B chooses returning 'linear deep ball', then A gains 1, B gains -1;
- A chooses stroking 'slash the ball deep', B chooses returning 'the deep ball' or 'slash the ball deep', then two payoff each as 0;
- A chooses stroking 'slash the ball deep', B chooses returning 'short oblique deep ball', then A payoff is -1, B payoff is 1;
- A chooses stroking 'short oblique deep ball', B chooses returning 'linear deep ball', then A gains 1, B gains -1;
- A chooses stroking 'short oblique deep ball', B chooses returning 'the deep ball' or 'slash the ball deep', then two payoff each as 0;
- A chooses stroking 'short oblique deep ball', B chooses returning 'short oblique deep ball', then A payoff is -1, B payoff is 1;

The game can use game tree to express as following Figure 8.

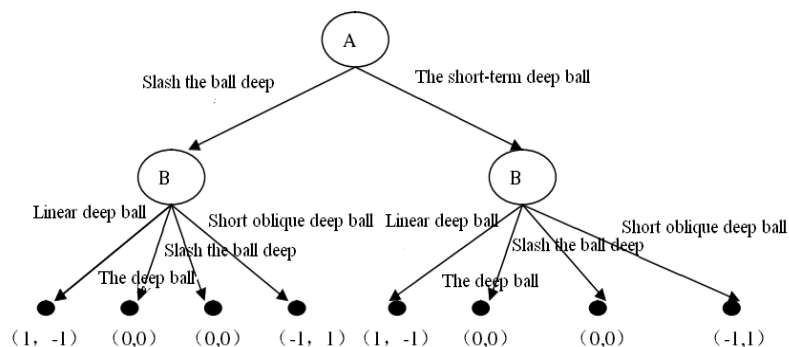


Figure 8: A and B game routes and payoff expansion form

Through above game tree analysis, we can conclude that no matter A choose 'slash the ball deep' or 'short oblique deep ball', 'linear deep ball' is always B's dominated strategy, with regard to the strategy, 'short oblique deep ball' is his dominant strategy. We use following matrix figure to express, problems would be more clearly, as following Figure 9.

		A	
		Slash the ball deep	The short diagonal balls
B	Linear deep ball	-1	1
	The middle deep ball	0	0
	Slash the ball deep	0	0
	The short diagonal balls	1	-1

Figure 9: A and B game matrix

Tournament court is as battlefield, players apply strategy and tactics through each changing trial with beating rivals as objective. World ranking top 50 men and women players all have outstanding techniques, every stroking will get superior quality warranty that can make better ball-control, never play any insignificant ball(refers to no intention, just take enter-in as stroking purpose). General most important tactical principle that top player implements is accumulating court advantages through applying dominant strategy, taking away opponent 'space' and 'time', and

make himself dominant in time and space; Meanwhile, try his best to avoid and eliminate dominated strategy, convert passive into initiative, in such process, look for opportunity, win the victory over the enemy.

CONCLUSION

Through research, it found that tennis competitive process had both dynamic game and static game. In tennis competitive game, tactics selection and tactics applying process essence and features were that it had tactics actions successive occurred sequential game and also strategy actions simultaneous occurred simultaneous game; in tennis tournament tactics selection and application in sequential game process, it could apply roll back backward induction, pursuing optimal strategy so as to get maximum payoff. In tennis tournament tactics application process, game strategy principle that player should apply was giving play to its strong points and avoiding its shortcomings, positively utilizing dominant strategy, avoiding dominated strategy. Game phenomenon widely existed in tennis tournaments, this paper's research only got involved in tournament partial tactical game aspects researching, suggested other scholars and experts to make more deeply researches, excavate game theory deepen application in tennis tactical aspect, establish a set of relative systematical tennis tournament game theory frame. Suggested tennis coaches and players to learn and improve game theory level and apply game strategies selection method into practical tournaments.

REFERENCES

- [1] Zhang B.; *International Journal of Applied Mathematics and Statistics*, **2013**, 44(14), 422-430.
- [2] Li Xing-Wei. *Journal of Henan Business Technical College*, **2011**, 24 (6), 45-48.
- [3] Zhang B.; Yue H.. *International Journal of Applied Mathematics and Statistics*, **2013**, 40(10), 469-476.
- [4] Niek Bollettieri. *Tennis magazine*, **2012**.
- [5] Rob Antoun, Zhang Wei compiles. *Tennis word*, **2011**, 79-80.
- [6] Zhang B.; Zhang S.; Lu G. *Journal of Chemical and Pharmaceutical Research*, **2013**, 5(9), 256-262.
- [7] Tong Yan-Hua. *Journal of Shenyang sports college*, **2013**. 32(3), 113-116.
- [8] Wang Hao. *Journal of Jixi University*, **2013**.13(3), 150-151.
- [9] Kong Xin-Liang. *Wuhan: Wuhan University*, **2007**.