Computer Shogi 2012 through 2014

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Computer shogi was first developed by the author and a research group in late 1974. It has been steadily improved by researchers and commercial programmers using game-tree making and pruning methods, opening and middle game databases, and feedback from research into tsume-shogi (mating) problems. It has now reached the top human-player level. In this paper, the author discusses contemporary computer shogi, especially how programs played against professional players and how they behaved at recent World Computer Shogi Championships.

1. Introduction

Almost forty years after starting to develop the first computer shogi program, the top computer programs have already reached the top human-player level. Here, the author offers a summary of the results of matches between computer shogi programs and professional players in section 2, a brief history of computer shogi in section 3, techniques used in computer shogi programs, including techniques adopted from chess programs and shogi-originated techniques, in section 4, a description of recent World Computer Shogi Championships, including their policies and rules, with profiles of recent finalists in section 5, and a conclusion in section 6.

This article is for people who either create computer shogi programs or just enjoy watching such events as the Den-O-Sen/World Computer Shogi Championships. The author would like to encourage people to enter the fascinating world of computer shogi.

2. Computer Shogi Programs Versus Professional Players

The top computer shogi programs reached professional 4-dan level at the 20th World Computer Shogi Championship in 2010. Usually, programmers of computer shogi are amateur shogi players, so they are often unaware of precisely how strong their program is. Therefore, watching and studying many games between computer shogi programs and professional shogi players is important for programmers to understand their own work better. Explanations by commentators is also needed.

The second Den-O-Sen (a five-game match between computer shogi programs and professional human players) was organized by Nihon Shogi Renmei (the Japan Shogi Association, or JSA) and Dwango Co., Ltd. (Dwango), in March and April, 2013. Computer shogi programs won the match by three wins, one loss and one draw. The third Den-O-Sen (a five-game match between computer shogi programs and professional human players) was organized by JSA and Dwango in March and April, 2014. Computer shogi programs won the match by four wins and one loss. The author discusses how computer shogi programs performed in these matches, which were excellent opportunities to expand our understanding of computer shogi.

2.1 First Den-O-Sen and Past Matches

The first match between a female professional player and a computer shogi program was an exhibition match at the 2001 MSO Japan, on July 29, 2001. A match was initially held between two invited programs, IS-Shogi and Gekisashi. The winner of the match would challenge Yamato Takahashi, female professional 2-dan. IS won both games (playing first and second) and became the challenger. The total time spent was 15 minutes plus 60 seconds byoyomi for both players. Ms. Takahashi played first and won the match. Ms. Takahashi said after the game, "IS-Shogi is about 1-dan in the opening, 4- or 5-dan in the middle game, and 3- or 4-dan in the endgame. It is not 1- or 2-dan but 3- or 4-dan throughout the game."

On September 19, 2005, Hokkoku Shimbun sponsored Takanori Hashimoto 8-dan vs. TACOS. Eventually, Hashimoto 8-dan won the match, but TACOS had the advantage in the middle game. After this match, the JSA prohibited professional players from playing against computer programs in front of an audience without authorization from the JSA.

On March 21, 2007, a match was held between Akira Watanabe Ryu-O and Bonanza. This was the first official match since Hashimoto's game. Daiwa Securities sponsored the match. It was a very close game; Watanabe Ryu-O eventually won. Watanabe Ryu-O said recently that he was lucky because in a critical position, a professional human player can find a winning move relatively easily, but this is not so for computer shogi programs.

On October 11, 2010, there was a match between the computer shogi system "Akara2010" and the female player Osho Ichiyo Shimizu. This match was sponsored by Komazakura (JSA), IPSJ, and the University of Tokyo. The total time spent was three hours plus 60 seconds byoyomi for both players. Akara2010 won the match.

The first Den-O-Sen was held on January 14, 2012. This was a match between a retired professional, the late Kunio Yonenaga, and a computer program, Bonkras (first player). Bonkras had been the winner of the 21st WCSC. This match was sponsored by the JSA, Dwango, and Chuokoron-Shinsha, Inc. The total time spent was three hours plus 60 seconds byoyomi for both players. Bonkras won the match.

2.2 Second Den-O-Sen

The second Den-O-Sen was a five-game match and was held in 2013 on the Saturdays of March 23 (Koru Abe (4-dan, won) vs. Shueso (second player)), March 30 (Shin'ichi Sato (4-dan)

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vs. ponanza (first player, won)), April 6 (Kohei Funae (5-dan) vs. Tsutsukana (second player, won)), April 13 (Yasuaki Tsukada (9-dan) vs. Puella alpha (the successor of Bonkras, first player), drawn as a result of Jishogi), and April 20 (Hiroyuki Miura (9-dan) vs. GPS (second player, won)). The author predicted that human players would win the match by 4 wins and one loss, but the prediction was wrong. The five computer programs had been first through fifth at the 22nd WCSC.

This match was sponsored by Dwango, and the JSA. The total time spent for each game was four hours plus 60 seconds byoyomi for both players.

It was a major surprise that A-class professional Miura was defeated.

Table 2.1 Results of Matches between
Professional Players and Computer Shogi Programs

Date	Event	Sponsor	Professional Player	Computer Shogi	Winner (draw)	Total Time Spent
2007.3.21	Daiwa Shoken Hai Special Match	Daiwa Securities	Akira Watanabe Ryu-O	*Bonanza	Watanabe Ryu-O	2 hours
2011.12.21	Den-O-Sen Practice Match	Dwango Co. ltd.	Kunio Yonenaga Eisei Kisei	*Bonkras	Bonkras	15 min.
2012.1.14	First Shogi Den-O-sen	JSA, Dwango Co. ltd., Cho-Koron-Shinsha Inc.	Kunio Yonenaga Eisei Kisei	*Bonkras	Bonkras	3 hours
2013.3.23	Second Shogi Den-O-Sen	Dwango ltd., JSA	*Koru Abe 4-dan	Shueso	Koru Abe 4-dan	4 hours
2013.3.30			Shin'ichi Sato 4-dan	*ponanza	ponanza	
2013.4.6			*Kohei Funae 5-dan	Tsutsukana	Tsutsukana	
2013.4.13			Yasuaki Tsukada 9-dan	*Puella alpha	draw	
2013.4.20			*Hiroyuki Miura 9-dan	GPS Shogi	GPS	
2013.12.31	Den-O-Sen Rematch	Dwango Co. ltd., JSA	*Kohei Funae 5-dan	Tsutsukana	Kohei Funae 5-dan	4 hours
2014.3.15	Third Shogi Den-O-Sen	Dwango Co. ltd., JSA	*Tatsuya Sugai 5-dan	Shueso	Shueso	5 hours (chess clock)
2014.3.22			Shin'ya Sato 6-dan	*Yaneura-O	Yaneura-O	
2014.3.29			*Masayuki Toyoshima 7-dan	YSS	Masayuki Toyoshima 7-dan	
2014.4.5			Taku Morishita 9-dan	*Tsutsukana	Tsutsukana	
2014.4.12			*Nobuyuki Yashiki 9-dan	ponanza	ponanza	
2014.7.19-20	Third Shogi Den-O-Sen Rematch	Dwango Co. ltd., JSA	*Tatsuya Sugai 5-dan	Shueso	Shueso	8 hours (chess clock)

Byoyomi is 60 seconds each. *first player

After the 2nd Den-O-Sen, the 23rd WCSC was held. Puella alpha did not enter, but other programs that had participated in the 2nd Den-O-Sen were 2nd (ponanza), 3rd (GPS Shogi), 6th (Tsutsukana), and 7th (Shueso). Bonanza was the winner, Gekisashi was 4th, and YSS was 8th. A newcomer, NineDayFever, came 5th.

Nobuyuki Yashiki 9-dan used GPS's moves at the second Den-O-Sen, against Hiroyuki Miura 9-dan, but Miura 9-dan won the match because he had already studied and modified the moves.

2.3 Third Den-O-Sen and the Future

The third Den-O-Sen was a five-game match and was held in 2014 on the Saturdays of March 15 (Tatsuya Sugai (5-dan) vs. Shueso (second player, won)), March 22 (Shin'ya Sato (6-dan) vs. Yaneura-O (first player, won)), March 29 (Masayuki Toyoshima (7-dan, won) vs. YSS (second player)), April 5 (Taku Morishita (9-dan) vs. Tsutsukana (first player, won), and April 12 (Nobuyuki Yashiki (9-dan) vs. ponanza (second player, one)). The five computer programs were first through fifth at the first Den-O tournament in November, 2013, which was sponsored by Dwango and the JSA. Ponanza was the winner of the first Den-O tournament and got the first Den-O title.

The author predicted that human players would win the match by 4 wins and one loss, again, because the programmers may not change their programs after the Den-O tournament and professional players were given the programs to study. But the prediction was wrong, again. The present author does not consider computer software to yet be superior to the skill of human professionals, but believes it now to be very close in strength to that of professionals.

It is not wrong to assert that computer shogi programs are now as strong as ordinary professional human players. The way computer shogi programs help human professionals has become the most important point. To verify Joseki or a middle game database is another.

After the 3rd Den-O-Sen, the 24th WCSC was held. Yaneura-O did not enter but other programs that had participated in the 3rd Den-O-Sen were 2nd (ponanza), 3rd (YSS), 7th (Tsutsukana), and 14th (Shueso). A three time participant Apery was the winner, NineDayFever was 4th, Gekisashi was 5th, Bonanza was 6th, and twice participant N4S was 8th.

3. A Brief History of Computer Shogi

Computer shogi was first developed by the author and a research group in November 1974. It has been steadily improved by researchers and commercial programmers using game-tree making and pruning methods, opening and middle game databases, and feedback from research into tsume-shogi (mating) problems.

In 1997, when Deep Blue beat Gary Kasparov, the strongest computer shogi program was a little stronger than an average club player. In 2002, Yoshimasa Tsuruoka, et. al., the developers of a computer shogi program "Gekisashi," installed their realization probability method and won the 12th and 15th championships. Gekisashi was invited to an Amateur Ryu-O tournament and was 16th, evaluated as close to top amateur shogi players. In 2006, Kunihiro Hoki, the developer of the computer shogi program "Bonanza", installed the "Bonanza Method" and won the 16th championship.

The results of the WCSCs are shown in Table 3.1. Ten programs have won the tournaments. Kanazawa Shogi has won five times, IS Shogi and Gekisashi four times each, YSS three times, Bonanza and GPS Shogi twice each, and Eisei

Meijin, Morita Shogi, Bonkras, and Apery once each.

Table 3.1 Results of the World Computer Shogi Championships

No.	Date	Number of Participants	Winner	Second	Third
1	1990.12.2	6	Eisei Meijin	Kakinoki	Morita
2	1991.12.1	9	Morita	Kiwame	Eisei Meijin
3	1992.12.6	10	Kiwame	Kakinoki	Morita
4	1993.12.5	14	Kiwame	Kakinoki	Morita
5	1994.12.4	22	Kiwame	Morita	YSS
6	1996.1.20−21	25	Kanazawa	Kakinoki	Morita
7	1997.2.8−9	33	YSS	Kanazawa	Kakinoki
8	1998.2.12−13	35	IS	Kanazawa	Shotest
9	1999.3.18−19	40	Kanazawa	YSS	Shotest
10	2000.3−8−10	45	IS	YSS	Kawabata
11	2001.3.10−12	55	IS	Kanazawa	KCC
12	2002.5.2−5	51	Gekisashi	IS	KCC
13	2003.5.3−5	45	IS	YSS	Gekisashi
14	2004.5.2−4	43	YSS	Gekisashi	IS
15	2005.5.3−5	39	Gekisashi	KCC	IS
16	2006.5.3−5	43	Bonanza	YSS	KCC
17	2007.5.3−5	40	YSS	Tanase	Gekisashi
18	2008.5.3−5	40	Gekisashi	Tanase	Bonanza
19	2009.5.3−5	42	GPS	Ootsuki	Monju
20	2010.5.2−4	43	Gekisashi	Shuso	GPS
21	2011.5.3.−5	37	Bonkras	Bonanza	Shuso
22	2012.5.3−5	42	GPS	Puella alpha	Tsutsukana
23	2013.5.3−5	40	Bonanza	ponanza	GPS
24	2014.5.3−5	38	Apery	ponanza	YSS

Kanazawa is the successor of Kiwame.
Puells alpha is the successor of Bonkras

3.1 Computer Shogi Association and the World Computer Shogi Championships

The Computer Shogi Association (CSA) was jointly established in 1986 by Yoshiyuki Kotani and the author. This organization started organizing computer shogi tournaments, the World Computer Shogi Championships (WCSCs), in 1990. The WCSCs are supported by the JSA.

3.2 Programs from Outside Japan

Many programs from outside Japan have entered the WCSCs. GNU shogi (Matthias Mutz, USA) entered once, Shotest (Jeff Rollason, UK) 12 times (and twice came third), SPEAR (Reijer Grimbergen, the Netherlands) 14 times, KCC Shogi (An KyongNam, North Korea) 9 times (once coming second and three times third), Shocky (Pauli Misikangas, Finland) 3 times (and once a finalist), Tejin (Tejin Potongan Soft, North Korea) once, Inaka Shodan (Till Plewe, Germany) twice, God Shogi (Larry Tu, Taiwan) twice, and Mumyo (David Wada, USA) five times.

4. The Art of Computer Shogi

Computer Shogi uses an alpha-beta tree pruning method with some ideas from computer chess and other completely new ideas.

4.1 Basic Technology

Many computer shogi programs use PVS (principal variation search), quiescence search, aspiration search, null move (forward) pruning, futility pruning, killer heuristic, history heuristic, iterative deepening, transposition hash tables, and singular extension, adopted from chess programs.

4.2 Realization Probability Algorithm

Before playing, professional players' moves are collected and categorized, then probabilities calculated, such as recapturing or capturing and gaining material, promoting a rook and gaining material, checking and gaining material, and so on. When playing, the programmer must evaluate the nodes if the probability (multiplied) is less than the threshold, otherwise must search deeper.

Yoshimasa Tsuruoka proposed this algorithm in 2002 and implemented it in the shogi program Gekisashi, winning the championships in 2002, 2005, 2008, and 2010.

4.3 Bonanza Method

Before playing, the programmer gathers professional players' move records in the form of textbooks. The subsequent steps are as follows: Prepare a linear evaluation function, and decide the initial coefficients of the function. Give many positions and find the best move for each, then compare it with the move in the textbooks. Count the number of moves for which the program moves and the textbook moves are identical and calculate the ratio of identical moves. If the ratio is high, then the coefficients are probably right, but if the ratio is low, then the coefficients are probably wrong. To adjust the coefficients, a numerical iterative method such as that used to solve partial differential equations is used. When playing, the program just use the evaluation function.

Kunihito Hoki proposed this algorithm in 2006 and implemented it in the shogi program Bonanza, winning the championships in 2006 and 2013.

In 2006, about thirty thousand coefficients were adjusted. Now more than forty million coefficients have been adjusted and this method has been further extended to non-linear evaluation functions.

4.4 Other Ideas

4.4.1 Consultation Algorithm

First implemented in Monju in 2009 by Takuya Obata, as follows: Give the root position to independent computers and receive the best move each (voting phase), and then decide the move by some algorithm, such as move with the best score, or just by majority (decision phase).

4.4.2 Loosely-Coupled Multi-Processor System with Parallel Search

The first computer shogi program using a multi-processor system was Super Shogi by Hisayasu Kuroda in 1997. This was an eight-computer system.

The first computer shogi using a loosely-coupled multi-processor system with parallel search was GPS shogi by Tetsuro Tanaka , Tomoyuki Kaneko, et al. in 2000. This system used 320 processors (666 cores).

GPS Shogi won the 22nd WCSC in 2012 and won against Miura 9-dan at the second Den-O-Sen in 2013 using such a system.

4.4.3 Df-pn (depth-first proof number search) algorithm

This derives from studying tsume-shogi (mating) problems. Unlike the case of chess, the number of possible moves in the endgame of shogi is the same as the number of possible moves

in the middle game. So a good algorithm for searching and/or tree is needed for solving tsume-shogi problems. Ayumu Nagai proposed this algorithm and implemented it in a tsume-shogi solver, succeeding in solving many problems.

5. World Computer Shogi Championships 2012 through 2014

The Twenty-Second World Computer Shogi Championship was held May 3-5, 2012. Forty-two teams (including one invited) entered, with GPS Shogi winning the championship for the second time. The Twenty-Third World Computer Shogi Championship was held May 3-5, 2013. Forty teams (including one invited) entered, with Bonanza winning the championship for the second time. The Twenty-Fourth World Computer Shogi Championship was held May 3-5, 2014. Thirty-eight teams entered, with Apery winning the championship for the first time.

5.1 World Computer Shogi Championship Policies

The following are the policies of the World Computer Shogi Championships (WCSCs) hosted by the Computer Shogi Association (CSA) declared on January 23, 2012.
1. The WCSCs are held for the purpose of deciding the strongest computer shogi at the time under conditions of fair and impartial operation.
2. The CSA imposes no restrictions on the hardware of any entrant for the WCSCs. Furthermore, any person may enter the WCSCs without restriction.
3. The CSA maintains interchange among developers at the WCSCs.

5.2 Excerpts from the Rules

The World Computer Shogi Championship is a championship in which representatives of outstanding technology compete against each other under set rules, team members of entered programs meeting at the same venue and demonstrating their technical achievements in the developing field of computer shogi. Each entered program should include ingenuity of a quality high enough to warrant entry in a global competition, having been expressly developed for that purpose by the team members. Any hardware/software technique is admissible if it meets the criteria outlined in rules below. Members of the teams should be willing to disclose the techniques used in a positive manner, thus contributing to the technological improvement of computer shogi.

Those who agree with these points and observe the rules may enter the championship.

Here is a brief selection of articles in the rules. The full version of the rules, the Library Rules for the World Computer Shogi Championship, and the TCP/IP Server Protocol are shown on the CSA webpage.

Article 6 (Entered program)
1. The entered program must run on a machine that is an artifact and automatically generates a move under the rules of shogi.

2. The entered program may use any number of computers and any peripherals.
3. Each machine must be prepared by the entrant.
4. The developer of the program may not develop two or more thinking parts of the programs that enter the championship.
5. The entered program is a program that the developer made expressly using some technical ingenuity, but it is possible to enter if the developer expressly used the library for that purpose.
6. The entered program must have all the functions that are written in the rules.

Article 7 (CSA module library)
1. An entrant may use the CSA module libraries that are registered at the specified time point, for his/her program.
2. The entrant may modify and use the modules. In this case, it is suggested that the entrant register a modified module as a library entry after the championship.
3. If the entrant uses the CSA module libraries, he/she must disclose this fact to the operating committee.

Article 8 (Required features)
An entered program must have the following features:
1. Be able to start/continue the game for any position, turn or time-spent.
2. Be able to quit at any point.
3. Display the current board position, pieces in hand, and the turn. It is acceptable to display this information in text.
4. Measure the time spent on each individual move and display the total time spent under Article 24.
5. Record the moves and the time spent on each move, showing the recorded moves and the time spent on each move when quitting the game.
6. Be able to play through a LAN server under CSA server protocol 1.1.3.
7. Be able to enter an opponent's move manually (without LAN).

Article 24 (Time spent)
1. The time spent is counted in seconds. The minimum time spent for each move is one second, i.e., if the time spent on a move is one second or less then the program must count it as one second. If the time spent on a move is more than one second, then the program must count in whole seconds, rounding fractions down if desired.
2. The total time spent is the sum of time spent.
3. Each program is allowed a total of twenty-five (25) minutes of playing time. If one side runs out of time before it wins or declares to win, then it loses the game, even if it mates on the move made when the total time spent is greater than or equal to the time limit.
4. The operating committee may reduce the time limit depending on championship procedures.
5. When playing through the championship server, the server counts the time spent for each move and manages the total time spent.

The time spent for a move is measured between the sending of the opponent's last move (or the server's initial order to start the game) and receiving the reply.　The delay time is included in the time spent.

6. When playing manually, the time spent is counted according to the time spent as counted by the program.

7. When playing manually and by remote participation, time spent is counted on the machine in venue.　The time spent includes the communication time and the reconnection time (for communication breaks).

8. When playing manually and using a front machine, time spent is counted on the front machine.　The time spent includes the communication time between the front machine and the move-generating machine.

5.3 Finalists

The following were recent finalists in the WCSCs.

5.3.1 Apery (Takuya Hiraoka, Ayumu Sugita, and Shuhei Yamamoto)

Apery won the 24th WCSC.　Used Stockfish-like search, Bonanza method for three-piece relationships, magic bitboard.

5.3.2 Bonanza (Kunihito Hoki)

Bonanza won the 23rd WCSC (2nd time), came 6th at the 24th WCSC.　A member of Akara 2010.　Used Bonanza method for a huge number of parameters, consultation algorithm.

5.3.3 GPS Shogi (Tetsuro Tanaka, Tomoyuki Kaneko, Daigo Moriwaki, Shunsuke Soeda, Yoshiki Hayashi and Shogo Takeuchi)

GPS won the 22nd WCSC (2nd time), came third at the 23rd WCSC.　It beat Miura 9-dan at the second Den-O-Sen in 2013.　A member of Akara 2010.　Used a loosely-coupled multi-processor system with parallel search, Bonanza method, realization probability algorithm, df-pn algorithm.

5.3.4 ponanza (Issei Yamamoto, Akira Shimoyama)

Ponanza was the runner-up at the 23rd and 24th WCSCs.　It won the first Den-O tournament in 2013 and became the first Den-O.　It won against Yashiki 9-dan at the third Den-O-Sen in 2014.　Shimoyama joined in 2014.　Used magic bitboard.

5.3.5 Puella alpha/Bonkras (Eiki Ito)

Puella alpha (Bonkras) was the runner-up at the 22nd WCSC. It beat Kunio Yonenaga, a retired but famous professional player at the first Den-O-Sen in 2012.　Used Bonanza method.

5.3.6 YSS (Hiroshi Yamashita)

YSS was 3rd at the 24th, 8th at the 23rd, and 7th at the 22nd WCSCs, respectively.　It won the WCSCs three times, and has been 8th or better in the 2nd (first time participating) through 24th WCSCs.　A member of Akara 2010.　Beaten by Toyoshima 7-dan at the third Den-O-Sen in 2014. Used a loosely-coupled multi-processor system with parallel search, Bonanza method.

5.3.7 Tsutsukana (Takanori Ichimaru)

Tsutsukana was 3rd in the 22nd WCSC.　It won against Funae 5-dan at the second Den-O-Sen in 2013 and won against Morishita 9-dan at the third Den-O-Sen in 2014.　Used Bonanza method with extension of reduction of moves.

5.3.8 NineDayFever (Yuji Kanazawa)

NineDayFever was fourth at the 24th and 5th at the 23rd WCSCs, respectively.　Used Bonanza method.

5.3.9 Gekisashi (Yoshimasa Tsuruoka, Daisaku Yokoyama, Takashi Maruyama, Ryo Takase, Takumi Oouchi)

Gekisashi was 5th at the 24th, 4th at the 23rd, and 6th at the 22nd WCSCs, respectively.　It won the WCSCs four times.　A member of Akara 2010.　Used a realization probability algorithm, Bonanza method, df-pn algorithm.

5.3.10 Shueso (Akira Takeuchi)

Shueso was 7th at the 23rd and 5th at the 22nd WCSCs, respectively.　Beaten by Koru Abe 4-dan at the second Den-O-Sen in 2013 and beat Sugai 5-dan at the third Den-O-Sen in 2014.　Used Bonanza method for non-linear evaluation function like a function from a three-layer perceptron in neural network, and df-pn algorithm.

5.3.11 N4S (Kenichi Yokouchi)

N4S was 8th at the 24th WCSC.　Used Bonanza method with extension of four-piece relationships.

5.3.12 Blunder (Akira Shimoyama)

Blunder was 8th at the 22nd WCSC.　Used Bonanza method and df-pn algorithm.　Shimoyama joined the ponanza team in 2014.

5.4 Results of the Finals in the 22nd through 24th WCSC

There were forty two (42) programs (including one invited) entered the 22nd WCSC.　GPS Shogi was the winner of the tournament.　If ponanza beat GPS Shogi at the last round, then Tsutsukana, ponanza or Puella alpha would be the winner.　The results of the final of the 22nd WCSC are shown in Table 5.1.

Table 5.1.　22nd WCSC Final Results (May 5, 2012)

No.	Program Name	1	2	3	4	5	6	7	Pt	SB	MD
1	GPS Shogi	6+	5+	8+	7+	3+	2-	4+	6.0	17.0	12.0
2	Puella alpha	5+	7+	6-	4-	8+	1+	3+	5.0	16.0	9.0
3	Tsutsukana	8+	6+	7-	5+	1-	4+	2-	4.0	11.0	6.0
4	ponanza	7+	8+	5-	2+	6+	3-	1-	4.0	11.0	5.0
5	Shueso	2-	1-	4+	3-	7+	8-	6+	3.0	9.0	3.0
6	Gekisashi	1-	3-	2+	8+	4-	7+	5-	3.0	8.0	2.0
7	YSS	4-	2-	3+	1-	5-	6-	8+	2.0	5.0	0.0
8	Blunder	3-	4-	1-	6-	2-	5+	7-	1.0	3.0	0.0

Winner of 22nd WCSC (Team GPS)

There were forty (40) programs (including one invited) entered the 23rd WCSC. Bonanza was the winner of the tournament. Even the top three programs lost twice, while every single program earned at least one point. This indicates that the top programs are all of remarkably comparable strength. For example, if GPS won the last round, GPS was the winner of the tournament. If Shueso (7th) beat YSS (8th) at the last round, ponanza would be the winner. The results of the final of the 23rd WCSC are shown in Table 5.2.

Table 5.2. 23rd WCSC Final Results (May 5, 2013)

No.	Program Name	1	2	3	4	5	6	7	Pt	SB	MD
1	Bonanza	5+	8+	6+	2-	7-	4+	3+	5.0	16.0	10.0
2	ponanza	8+	7+	5-	1+	6+	3-	4+	5.0	15.0	9.0
3	GPS Shogi	7+	6+	8+	5+	4-	2+	1-	5.0	14.0	8.0
4	Gekisashi	6+	5-	7+	8+	3+	1-	2-	4.0	11.0	5.0
5	NineDayFever	1-	4+	2+	3-	8+	7-	6-	3.0	10.0	4.0
6	Tsutsukan	4-	3-	1-	7+	2-	8+	5+	3.0	6.0	2.0
7	Shueso	3-	2-	4-	6-	1+	5+	8-	2.0	8.0	0.0
8	YSS	2-	1-	3-	4-	5-	6-	7+	1.0	2.0	0.0

Winner of 23rd WCSC (Kunihito Hoki)

There were thirty eight (38) programs entered the 24th WCSC. Apery was the winner of the tournament. Apery and ponanza was 5 wins and two losses each, and YSS won both Apery and ponanza. Ponanza which won the first Den-O tournament and the runner-up at the 23rd WCSC was the runner-up, again. YSS which entered the WCSCs 23 times and 8th of better for all participated tournaments was 3rd. If ponanza won the last round, ponanza was the winner of the tournament. If NineDayFever won the last round, it would be the winner. The results of the final of the 24th WCSC are shown in Table 5.3.

Table 5.3. 24th WCSC Final Results (May 5, 2014)

No.	Program Name	1	2	3	4	5	6	7	Pt	SB	MD
1	Apery	4-	6+	7+	5+	3-	2+	8+	5.0	15.0	10.0
2	ponanza	5+	7+	6+	8+	4+	1-	3-	5.0	14.0	10.0
3	YSS	6-	5-	4-	7+	1+	8+	2+	4.0	13.0	8.0
4	NineDayFever	1+	8+	3+	6-	2-	7+	5-	4.0	12.0	7.0
5	Gekisashi	2-	3+	8+	1-	7-	6+	4+	4.0	11.0	7.0
6	Bonanza	3+	1-	2-	4+	8+	5-	7-	3.0	8.0	4.0
7	Tsutsukana	8+	2-	1-	3-	5+	4-	6+	3.0	7.0	3.0
8	N4S	7-	4-	5-	2-	6-	3-	1-	0.0	0.0	0.0

Winner of 24th WCSC (Apery Team)

6. Conclusion

The top computer shogi programs have already come close to top human-player level. Yoshiharu Habu Meijin predicted about ten years ago that the top programs would be close to the top human-player level in ten years. His words were prophetic. Many professional players understand how strong top computer programs have become, as do many people seeing the Den-O-Sens and reading newspapers describing the results.

Computer shogi programs have become the helpful partners of professional players, who now use computer shogi for verifying their studies, for example. Daisuke Nakagawa 8-dan observed the 18th WCSC and also the exhibition between Tanase Shogi (the runner-up) and top amateur player Toru Kato. Tanase Shogi won the game. Nakagawa studied this and won his professional games three times, including that versus Akira Watanabe. Toshiyuki Moriuchi Ryuo studied ponanza's moves and used them at the Meijin match versus Yoshiharu Habu in 2013, winning the game and the match.

Professional players now make a careful study of moves such as GPS's attacking move against Miura 9-dan and YSS's king move against Toyoshima 7-dan.

The human chess game is still active, although computer chess programs are now stronger than the strongest human player. The relation between human shogi players and computer shogi programs will be the same as the relation between human chess players and computer chess programs in five years. But there are further problems ahead. For example, the winning ways of shogi still remain.

A. Appendices

The author presents some positions from professional game and Den-O-Sen games, with the game record from the rematch of Sugai 5-dan vs. Shueso.

A.1 Meijin match between Moriuchi and Habu in 2013.

Toshiyuki Moriuchi Ryu-O studied a ponanza's move and applied the move in the fifth game of the Meijin Match in 2013 and won the game.　The position is shown in Fig.. A.1.

White: Toshiyuki Moriuchi Meijin
White in hand: S P2

```
    9   8   7   6   5   4   3   2   1
  +---------------------------+
  |wL  wN   *   *   *   *   * wN  wL |a
  |  * wR   *   *   * wS  wG  wK   * |b
  |  *   * wB   *   * wG   * wP  bP |c
  |  *   * wP   * wP  wP  wP   *   * |d
  |wP  wP   * wP   *   *   * bN  wP |e
  |  *   * bP   * bP   *   * bP   * |f
  |bP  bP bS  bG   * bP   *   *   * |g
  |  * bK  bG  bB   *   * bR   * bL |h
  |bL  bN   *   *   *   *   *   *   * |i
  +---------------------------+
```

Black: Yoshiharu Habu 3-crown
Black in hand: S
up to 31.P*1c.

Fig. A.1 Habu vs. Moriuchi (Meijin match in 2013)

Next Move: S*3g by White.

A.2 Fourth game of Second Den-O-Sen

The game between Puella alpha and Tsukada 9-dan at the fourth game of the second Den-O-Sen was not a good game but it was the most impressive game in the second Den-O-Sen games.

It was Puella alpha's favor almost all over the game, but Tsukada 9-dan changed the strategy and tried to manage the game to Jishogi position.　Finally he succeeded.　The final position is shown in Fig. A.2.　If kings of both sides each may safely enter the opponent's territories and both sides each has 24 piece points or more, then the game is draw by Jishogi.　Piece points are counted only for pieces that are in hand or in the safe positions.　Piece points are counted as follows:　King: 0; Rook, Bishop, Promoted Rook, or Promoted Bishop: 5; Other: 1. For the position in Fig. A.2, White has 24 piece points while Black has more than 24 piece points.　White proposed Jishogi and Black agreed so that the game was draw.

White: Yasuaki Tsukada 9-dan
White in hand: B G N2 L P3

```
    9   8   7   6   5   4   3   2   1
  +---------------------------+
  |bK   *   *   * bN+  * bP+  * |a
  |  * bP bN+bP+  * bP+  *   * bP+|b
  |  *   *   *   *   * bP+bP+  *   * |c
  |  *   *   * bL+bP   * bS+  *   * |d
  |bS  bR+bB+  *   *   *   *   *   * |e
  |  *   * bP   *   * wS   *   *   * |f
  |bP  wP+wP+wR+  * wP+  * wP+wL+|g
  |  *   *   *   *   *   *   * wL+wK |h
  |  *   *   *   *   *   *   *   *   * |i
  +---------------------------+
```

Black: Puella α
Black in hand: G3 S P
up to 115...+Px2g.　(Jishogi)

Fig. A.2 Puella α vs. Tsukada (4th game of Second Den-O-Sen in 2013)

A.3 Fifth game of second Den-O-Sen

Miura 9-dan was the second of A class (meijin challenger deciding round-robin tournament, 10 professional players) in 2012-2013.　He beat Habu, the challenger at the tournament. His strategy against GPS shogi was similar to vs-Habu game, but eventually lost the game.　Miura 9-dan downplayed GPS's attack sequence from the position in Fig. A.3.

White: GPS Shogi
White in hand: nothing

```
    9   8   7   6   5   4   3   2   1
  +---------------------------+
  |wL  wN   *   *   *   * wN  wL |a
  |  * wR   *   *   * wG  wK   * |b
  |wP   * wS  wP   * wG  wS  wP   * |c
  |  *   * wP  wB  wP  wP  wP   * wP |d
  |  * wP   *   *   *   * bP   * |e
  |  *   * bP  bP  bP   * bP   * bP |f
  |bP  bP bS  bG   * bP  bS   *   * |g
  |  * bK  bG  bB   *   * bR   * |h
  |bL  bN   *   *   *   * bN  bL |i
  +---------------------------+
```

Black: Hiroyuki Miura 9-dan
Black in hand: nothing
up to 20.B-6h.

Fig. A.3 Miura vs. GPS Shogi (2nd Den-O-Sen in 2013)

Next three moves: P-7e, Px7e, S-8d.

A.4 Third Game of the third Den-O-Sen

YSS was beaten by Masayuki Toyoshima 7-dan at the third game of the third Den-O-Sen in March, 2014.　But YSS showed a new challenging move in this game.　After the third Den-O-Sen, many professional players studied the move and have realized that the move was reasonable.

White: YSS

White in hand: P2

```
      9  8  7  6  5  4  3  2  1
     +---------------------------+
     |wL wN wS wG wK  *  * wN wL |a
     | *  *  *  *  *  * wG wS  * |b
     |wP  * wP wP wP wP wB  * wP |c
     | * wR  *  *  *  *  *  *  * |d
     | *  *  *  *  *  *  *  *  * |e
     | *  * bP  *  *  *  * bR  * |f
     |bP bP  * bP bP bP bP  * bP |g
     | * bB bG  *  *  *  *  *  * |h
     |bL bN bS  * bK bG bS bN bL |i
     +---------------------------+
```

Black: Masayuki Toyoshima 7-dan

Black in hand: P2

up to 11.P*8g.

Fig. A.4 Toyoshima vs. YSS (3rd game of Third Den-O-Sen in 2014)

Nest move: K-6b by White.

A.5 Rematch after third Den-O-Sen

After the third Den-O-Sen, there was a rematch of Tatsuya Sugai (5-dan) vs. Shueso. Total time spent was 8 hours each and Sugai played first.

Black: Tatsuya Sugai 5-dan

White: Shueso

1.P-7f	P-8d	2.S-6h	P-3d	3.P-6f	S-6b
4.P-5f	P-5d	5.G4i-5h	S-4b	6.G-7h	G-3b
7.K-6i	K-4a	8.G5h-6g	P-7d	9.P-2f	S-3c
10.S-7g	G-5b	11.B-7i	B-3a	12.P-2e	P-4d
13.S-3h	G5b-4c	14.S-2g	S-7c	15.S-2f	P-7e
16.Px7e	Bx7e	17.S-1e	S-2b	18.P-2d	Px2d
19.P*2c	Sx2c	20.Sx2d	Sx2d	21.Bx2d	P*2c
22.B-6h	K-3a	23.K-7i	B-4b	24.K-8h	K-2b
25.P*2d	Bx2d	26.Bx2d	Px2d	27.Rx2d	P*2c
28.R-2h	B*4i	29.P-4f	S-6d	30.P-4e	Px4e
31.P*4d	Gx4d	32.B*7a	R-4b	33.S*5b	S*6i
34.G7h-6h	P-4f	35.Sx6c+	P-4g+	36.+Sx6d	+P-3h
37.R-1h **(Fig. A.5)**	K-1b	38.P-9f	G4d-4c	39.P*4d	Gx4d
40.S*5a	R-4a	41.Gx6i	Bx6g+	42.S*5b	R-4c
43.Sx4c+	G4dx4c	44.R*7b	S*3a	45.B-6b+	+Px2i
46.+S-5c	G4c-3c	47.S-4b=	+Px1i	48.R-7h	P*7f
49.Sx7f	+Bx6f	50.P*7g	Sx4b	51.+Sx4b	Gx4b
52.+B-5a	G4b-3b	53.R-6h	+B-4d	54.S*4e	+B-4c
55.+Bx3c	+Bx3c	56.Sx3d	+B-2b	57.Rx3b+	+Bx3b
58.G*4c	+Bx4c	59.Sx4c+	S*3a	60.B*5c	G*4a
61.Bx3a+	Gx3a	62.S*3b	S*2b	63.G*4b	Gx4b
64.+Sx4b	B*2e	65.P-3f	P-1d	66.G*3e	P*6g
67.Sx6g	L*8e	68.S-7f	P*6g	69.R-2h	R*4i
70.Rx2e	G*3c	71.P*2d	Gx3b	72.G-3d	S*7i
73.resigns					

Game Record of Rematch after 3rd Den-O-Sen

White: Shueso

White in hand: P4

```
      9  8  7  6  5  4  3  2  1
     +---------------------------+
     |wL wN bB  *  *  *  * wN wL |a
     | *  *  *  *  * wR wG wK  * |b
     |wP  *  *  *  *  *  * wP wP |c
     | * wP  * bS+wP wG wP  *  * |d
     | *  *  *  *  *  *  *  *  * |e
     | *  *  * bP bP  *  *  *  * |f
     |bP bP bS bG  *  * bP  * bP |g
     | * bK  * bG  *  * wP+  * bR |h
     |bL bN  * wS  * wB  * bN bL |i
     +---------------------------+
```

Black: Tatsuya Sugai 5-dan

Black in hand: S P

up to 37.R-1h.

Fig. A5. Sugai vs. Shueso (Rematch of 3rd Den-O-Sen in 2014)

Next move: K-1b.by White. Eventually, Shueso won the game.

References

1) Kunihito Hoki: "Optimal control of minimax search results to learn positional evaluation", 11th Game Programming Workshop (GPW2006), pp. 78-83, in Japanese, 2006.

2) Kunihito Hoki and Tomoyuki Kaneko: "Large-Scale Optimization for Evaluation Functions with Minimax Search", Journal of Artificial Intelligence Research, 49, pp. 527-568, 2014.

3) Takenobu Takizawa: "Computer Shogi Programs Versus Human Professional Players through 2013", Proceedings of the Game Programming Workshop, 2013.

4) Takenobu Takizawa, "Contemporary Computer Shogi (May 2013)", Proceedings of Game Informatics 30-1, 2013.

5) Takizawa, Grimbergen: Review: Computer Shogi through 2000, in Marsland and Frank (eds.) Computers and Games, Lecture Notes in Computer Science 2063, Springer Verlag, 2001.

6) Yoshimasa Tsuruoka, Daisaku Yokoyama, and Takashi Chikayama: "Game-tree Search Algorithm based on Realization Probability", ICGA Journal, Vol. 25, No. 3, pp. 145-152, 2002

7) Junichi Takada: "The Computer Shogi Association Web Page" http://www.computer-shogi.org/index_e.html