Computer Shogi－The History and the Techniques

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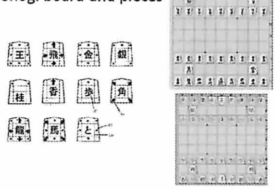
Introduction

- Shogi(将棋) is a game with the same origin as chess and xiangqi , played in Japan.
- Computer shogi studies started in the 1970s.
- Nowadays, it has reached professional players' strength.
- Many technologies, peculiar to computer Shogi, have developed as well as application of chess knowledge, such as: end-game search, realization probability search, evaluation function learning, etc.
- I will talk about this history of this computer Shogi with the technical development.

Outline

- What is shogi?
- History of computer Shogi
- Techniques and Algorithms
  - －Many techniques
  - －Realization probability sea
  - －Bonanza method
  - －Endgame search
- How strong and systems
- Next match and future



Shogi board and pieces

What is Shogi?

- It has the same origin as western chess and Xianqi
  - －the origin is in India
  - －various chess games are distributed in Eurasia
- It is disputed whether first Shogi came from south or west
  - －my opinion is from south
  - －Shogi and Xianqi are brothers
- The significant rule:
  - －captured pieces can be used by dropping it on a vacant square
  - －dropping moves
- Shape of pieces
  - －No difference between first and second player's pieces
  - －for the reuse
  - －Correctly there is a little difference in King
- 王 for upper grade, older, or second player
- 玉 for lower grade, younger, or first player

Special rules

- prohibited moves
  - －double pawn(二歩)
  - －non-movable piece
  - －dropping-pawn checkmate(打歩詰)
  - －continuous check perpetual move(連続王手千日手)
- draws
  - －perpetual move(千日手)
  - －mutual migration of kings to opponents' territory(入玉)

Shogi People

- population: 12 million -- 10% of Japanese
  - －Go has 4 million
- 157 professional players
  - －Go has 450 professionals
- organization
  - －Japanese Shogi Association(日本将棋連盟) the union of professional players
  - －many local amateur groups
  - －also groups of endgame Shogi problem

Computer Chess: Before the History

- Artificial brain machine was an imaginary goal for scientists for long ago. Playing chess was understood as its example.
- People already thought computer chess in 1950, when first computers started working:
  - －Shannon's and Turing's algorithms
  - －match between paper algorithm document and a novice woman
- In 1960s and 1970s, computer chess became strong, when most of fundamental techniques were invented such as αβ search, transposition table, etc.
- Deep blue defeated Gary Kasparov in 1997

History of Computer Shogi

- 1970s first computer Shogi programs
  - －including Takenobu Takizawa's(inFORTRAN) and Kotani's(in LISP) *
- 1980 first Shogi matches among programs
  - －Takizawa's, Kotani's and Osaka Univ.'s
- 1980～ Commercial Computer Shogis were made on PC(PC98,FM-7,MSX etc.) and FAMICOM, around 10 kyu
- 1986 CSA(Computer Shogi Association) was established
- 1986-1987 Tournament in Yomiuri Weekly Magazin
  - －8 comercial softwares
- 1990 amateur 2-3kyu
- 1990～ Computer Shogi Championship tournament

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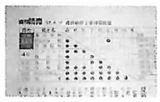


- 1990～ various activity started
  - －conferences: GPCC,GPW,CG
  - －1990 first Computer Shogi Book
  - －1994 Translation of Computer Chess Book (D. Levi and M. Newborn)
- 1990～ Computer Shogi Championship tournament
  - －annual, 21 times
  - －around 50 participants, 3days
- 1997 longest endgame problem "Microcosmos" was solved
  - －solution has 1519 plies
- 1999 df-pn algorithm (proof-number search for checkmate)
- 2000 realization probability search (flexible game tree depth)
- 2005 amateur 5dan or more
- 2006 BONANZA method (tuning of huge parameter set in position)
- 2007 in the range of professionals
- 2009 BONANZA source code made open
- 2010 a female professional defeated
- 2012 former Grandmaster defeated

An epsode of starting CSA in 1986

- A pair of Englishmen visited me, bringing a prototype Shogi machine, to find a commercial partner. It was a very sophisticated one, and has a Shogi board which recognizes piece moving with magnet sensor, though its CPU was Z80.
- I planned an amusing event to call Kazuo Morita who had made Morita Shogi, which was believed the strongest and well-sold software, and to make a match between them.
- The match was held at Nob Yoshigahara's Studio in Tokyo.
- The result Shogi machine defeated Morita Shogi which used 16-bit CPU 8086.
- We found such communication is much joyful, and then I gathered many people who made or were interested in computer shogi. It was the start.
- I wonder the Shogi machine was sold well or not.

Computer Shogi Data and Algorithms

- Data structure of position and move
- αβ tree search
- Iterative deepening
- Transposition table(TT)
- Move ordering
- Quiescence search or Capture search
- Extension and Pruning
- Fractional Number Extension
- Realization Probability Search
- End game and Proof-Number Search
- Opening
- Evaluation function and BONANZA parameter learning method
- Parallel Processing

Computer Shogi Data Structure

- position data
  - captured pieces
  - bit board often used
- data of a move
  - depends on whether backward position generation is needed or not
  - if needed
- from_xy, to_xy, from_piece, to_piece, captured _piece
- attack table

Game tree search : αβ pruning

- the most fundamental algorithm since 1960s
- effective min-max strategy
- write in Negamax method
- often Window search,
  Scout method embedded
- pruning methods embedded

Iterative deepening

- main routine calls αβ search iteratively, deepening its search depth by 1 (or 0.5)
- purposes:
  - generate move ordering information for deeper search
- kept in transposition table
  - for thinking time control
- time efficiency is little worse, because shallower searches are shorter enough than the last

Transposition Table

- the mechanism not to search the same position again
  - the possibility is high in Shogi
    A-B-C / C-B-A
    A(promoting)-B(capture) / A(not promoting)-B(capture)
- hash table
  - collision is ignored usually overwriting keeping shallower node etc.
- data in it
  - evaluation value, depth, exact/upper limit/lower limit
  - the best move for the position
  - sometimes the move list
- other TT
  - partial hash: TT without pieces in hand
  - the TT of endgame search is different one, whose values have to be kept correctly

Move Ordering

- necessary for efficient search
- by what?
  - the evaluation value in TT
    - the content saved in the last iteration
  - values in light evaluation function
  - the result of one-ply search
  - various heuristics like killer move
  - combined with move generation in past

Quiescence search or capture search

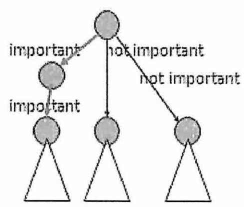
- their meaning is similar
- it is hard to be quiet in Shogi
- search only by :
  - capturing moves
  - escaping moves
  - sometimes
    attacking moves, double attacking moves, check moves
- often exclude pawn capturing moves
- mutually capturing search on the square of the last move

Extension and Pruning

- forward pruning(selected search) was dominated in past
- complete-width search + extension + short pruning + capture search
- extension
  - check extension
- short pruning
  - futility pruning, prob cut, null move pruning

Fractional Number Extension

- delicate, precise extension can be described
- to decrease the depth of search function by fractional number
- Yamashita's 0.5 move extension
  - for top move of move ordering




```
search(pos,alpha,beta,depth){
   if(depth<=0) return eval(  );
   generate moves;
   move ordering;
   for(next positions){
      w= -search(next position,-beta,-ma
                    d - fractional value)
      if(w>max)max=w;
      if(max>=beta)return max;
   }
   return max;
}
```

Realization probability search

- data based tree expansion
- Prof. Yoshimasa Tsuruoka invented and implemented it in Gekisashi System

- Historically investigated what kind of moves should be looked forward in tre
- A kind of fractional number search
- Based on probability of playing for a move
- In practice, the conditional probability:
  p<m> = p(move m is played | m is in category c)
- This value is calculated by many professional play records:
  (the # of the played moves of category c) /
  (the # of the moves of category c in possible move list)
- The probability that the variation $m_1, m_2, \ldots, m_d$ is played is estimated:

$$p < m_1 > p < m_2 > \cdots p < m_d >$$

- When this value become equal or less than a constant D, then stops looking ahead

```
search(pos,alpha,beta,depth){
  if(depth<=0) return eval( );
    :
  for(next position by move m){
     w= -search(next position,-beta,-max.
                    d – (-log p<m>));
       :
  }
   return max;
}
```

- example of p<m>
  - p<normal move> = 1/100
  - p<important move> = 1/10 : check, capture
  - p<meaningless move> = 1/10000
  - they consume the depth 1, 0.5 and 2

Opening database

- It gives the best move for completely matched positions in database
- It is made from professional record of play automatically
  - whole covered data: the system knows everything!
- Castle making
  - There is castle making phase after opening database tracking
  - It was an important part in past
  - Evaluation function and search generates castle making, because good evaluation functions were developed now

The evaluation function of Shogi

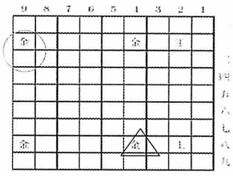
- It gives the advantage/disadvantage grade of a position
- Fundamentally piece value based
- Piece value is dependent upon its location on board and relation with the kings
- Values of pieces in hand are important
- the speed of the evaluation is required:
  - speed and correctness are in trade-off relation
- Hoki made an excellent method of generating the function, known as BONANZA method

BONANZA method: learning of evaluation function parameters

- Kunihito Hoki won WCSC championship in 2006 by this method
- His evaluation function has huge number of parameters, and he succeeded making learning mechanism for them
- parameters
  - values for relation among 2or3 piece locations
  - Especially piece and king relation

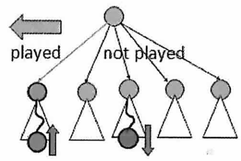
  weight[piece][piece_location][my_king_location]
  14 x 81 x 81

  example: **weight[GOLD][98][28]**



- learning method
  - TD(temporal difference) learnir
  - **learning between brother positions**

data for learning
  - self match data
  - problem collection
  - **professional record of play**



- it learns to increase the value of played position and to decrease that of not played
- unusual phenomenon: the value of Bishop low
- the match against Akira Watanabe who has the title Ryuo in 2007
- Several participants for WCSC championship used its open library and became very strong

On endgame

- chess-like endgame database methods are not used
  - The number of pieces does not decrease
  - Retrograde analysis cannot be used like chess
- only one move checkmate is coded
- instead **Checkmate search** has a big role in Shogi
  - embedded in usual search
  - systems became extremely strong in last stage

Checkmate Search

- an embedded partial search in αβ search
  - in root node and shallow nodes
- not min-max search but AND/OR search
- Possible moves are restricted as:
  - offence side: check moves
  - defense side: defense moves against check
- Return value is Boolean
  - true: checkmate variation is found (offence side's win)
  - false: not found
- Two directions: against first and second kings

Study on Checkmate Search

- Long history since around 1990
  - Simple depth-first search first
  - Best-first searches were made
  - Many method of heuristics were made which select first moves to look ahead
- The algorithm is used to solve Endgame problems(詰将棋) as well as checkmate search
- Masahiro Seo succeeded to make an efficient solving algorithm Seozume in 1998
  - Can solve long move sequence endgame problems
  - Used the concept "Conspiracy Number"
  - renamed as "Proof Number" related with other study
- Afterwards proof number searches were made and succeeded:

—Best-first search
—df-pn (depth-first pn search) by Ayumu Nagai 1999

Proof Number(pn) and Disproof Number(dn)

- Proof number searches are symmetrical on sides
- Proof number for a position:
  —The number of positions to prove it is true
- Disproof number for a position:
  —The number of positions to prove it is false
- Proof number searches act easiest positions first
  —They have lower proof/disproof numbers
- A true position: pn=0,dn=∞ A false position: pn=∞,dn=0
- A new(terminal) position:pn=1,dn=1
- A non-terminal position:
  —pn=minimum of its child positions' dn's
  —dn=sum of its child positions' pn's

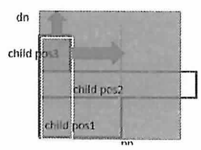
Outline of df-pn

- depth-first search
- iterate recursive call for the easiest child positions
- until target df or pn is found
- it is called by the code:

```
pn=∞;
dn=∞;
search(position, &pn &dn);
```

- the result is given by the return values:
  dn=∞ : positive solution
  pn=∞ : negative solution

```
search(position p, *pn, *dn){
  if(p is in TT and pnTT>=pn or
dnTT>=dn){pn=pnTT;dn=dnTT;return;}
  if(p has no child) ){pn=∞;dn=0;save it to TT;return;}
  generate children of p;
  repeat{
    sum_p= the sum of their pns;
    min_d= the minimum of their dns;
    if(min_d>=pn or sum_d>=dn)
        {pn=min_d;dn=sum_d;save it to TT;return;}
    recursive call to the child whose dn gives min_d;
}
```



- recursive call tries to add pn or dn of position 3, if it has the smallest dn
- it works in a loop till it reaches to the target dn (the arrow upward),
- or to next minimal dn of children (the arrow rightward)

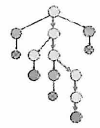
Endgame Problems(Tsume Shogi)

- Most of enjoyed endgame problems are Tsume Shogi
- there are many enthusiasts, and often felt as art
- long history since 400 years ago
- Tsume Shogi has been defined logically
  —Possible moves are the same as checkmate search
  —The solution is unique

Definition of Tsume Shogi

1.endgame position : a position in defense turn where there is no defense move
2.solvable position
  —endgame position
  —a position in offence turn such that at least one child is solvable
  —a position in defense turn such that all children are solvable
3.Tsume variation : a move sequence for a solvable position such that
  —null sequence (endgame position)
  —the move to a solvable position + Tsume variation after it (a position in offence turn)
  —the longest one of "a move + Tsume variation after it" (a position of defense turn)

- Tsume Shogi is defined as a solvable position such that:
  —all positions in offence turn on its Tsume Variation have only one move to a solvable child position.
- The solution is the Tsume variation.



Ability of Checkmate Search to Tsume Shogi

- After developed enough, almost all famous Tsume Shogi problems were solved including Microcosmos (below) by Koji Hashimoto which has the longest solution: 1519 plies
- In hundreds of historically famous problems, tens of errors were newly found as "no solution" and "unexpected solution".
- Tsume Shogi generation was also studied and succeeded to made short ones

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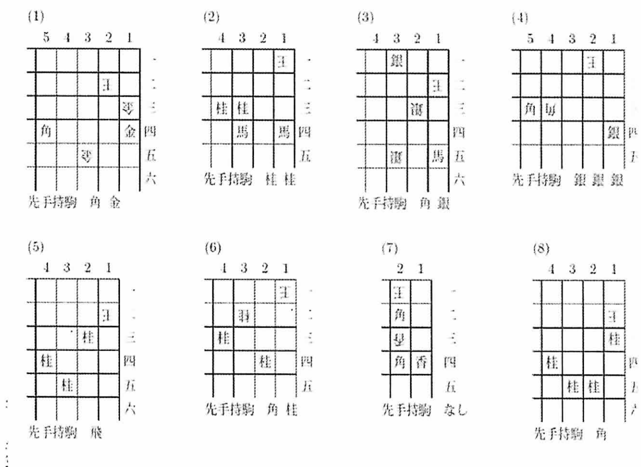
Machine Generated Tsume Shogis



Parallel Processing

- Thread programming on multi core machines is widely used
- YBWC
  1.calculate the first child
  2.then parallel processing for the second child to the last
- opinion combining
  —the first idea is 3Hirn
  —act on independent machines
  —Akara system defeated a female professional in 2010
- Parallel machines
  —usual multi-core PC, Playstation, FPG, PC cluster

How strong computer shogi systems are

- I estimated the rating of computer Shogi in the distribution of professional players
  - —Matches between professional players and computer Shogi ws decreased
- Shogi Association prohibited easy matches in 2005
- Permission and enough sponsorship are needed
  - —Estimation by circumstantial evidence
  - **—Computer Shogi exceeded the average of professionals in 2009 at latest**
- Computer Shogi grows about 100 per year in rating

ELO Rating of Humans and Computers(short games)

Grandmaster Habu	**3179**
4 top rank players	3071—3166
professional av.+2σ	**3058**
estimated computer(2011)	**2900**
estimated Yonenaga(retired)	**2800**
professional av.	**2696**
top amateur	2592
amateur(match with pro)	2494
estimated computer(2007)	**2500**
female pro. av.	2382
professional av.-2σ	2334

January 14 Match

- We had a epoch making match of human vs. computer
- Jan. 14, 2012
- Human player
  - —Kunio Yonenaga!
- Computer Shogi
  - —Bonkuras, by H. Ito
- Sponsor : Dwango
- Time limit
  - —3 hours total
  - —1 minutes per a ply after consumed

(from Ascii Weekly)

Kunio Yonenaga

- The president of Japanese Shogi Association
- Joyful, self-confident, verbose person
  "My elder brothers entered University of Tokyo because they have bad brains. I became a Shogi player because I have a good brain."
- He got 19 titles, which is the fifth best in history, including
  - —Meijin(Grandmaster) 1 period
  - —10 Dan 2 periods
  - —Kisei 22 periods
- got the name Eternal Kisei
- 68 years old
- retired as professional player
- challenging to recover the state before retire
- training
  - —against aging
  - —4 fours per day
- Professional players estimated his current rank
  - —30th to 40th among professionals
  - —without opening
- said "the last big match in my life"

Bonkuras

- Computer Shogi: Bonkuras
  - —by Hideki Ito
  - —Bonanza method based
  - —3 pc combined
- The winner of the championship in 2011

	Program	1	2	3	4	5	6	7	Win	Lost	Tie	SB	MD	Rank
1	Gekisashi	5○	6△	7○	8×	3×	4×	2○	3	3	1	11.0	4.0	4
2	Shuso	8○	7○	6○	4×	5×	3○	1×	4	3	0	10.5	5.0	3
3	GPS	7×	5×	8○	6×	1○	2×	4○	3	4	0	10.5	3.5	6
4	Bonanza	6○	8○	5×	2○	7○	1○	3×	5	2	0	15.0	9.0	2
5	Bonkuras	1×	3○	4○	7○	2○	8×	6○	5	2	0	17.5	10.5	1
6	Ponanza	4×	1△	2×	3○	8○	7○	5×	3	3	1	7.0	2.0	5
7	YSS	3○	2×	1×	5×	4×	6×	8○	2	5	0	5.0	0.0	8
8	Blunder	2×	4×	3×	1○	6×	5○	7×	2	5	0	8.5	0.0	7

- The result of 2011 championship
  final league, round robin matches,
  25 minutes limit

The result

- estimated computer rating 2900
- estimated Yonenaga's rating 2800
  - —for now, though 3100 or more in his peak
- human advantage of long limit time(3 hours)
- My estimation was even: 2900=2800+100
- Yonenaga made a good fight
  made unusual opening, made long term planning
  avoided piece exchange, occupied the center
- But then .....Yonenaga was defeated.

Future

- We are planning 5 vs. 5 matches next year
  Top five computers
  Five various rank young professionals
  (perhaps Yonenaga included)
- Afterward it should be the time of the match against the Grandmaster because It seems very near that computer exceeds humani n 3 years
- But Sponsor is wanted
  Yonenaga requests 800 million yen($ 10 million)
  to keep Grandmaster Habu in one year training
- Human side research on Computer Shogi is not enough yet
  - —Possibility of several year delay of the day by human systematic study
  - —As for chess delayed from 1994 to 1997
- to make a hybrid strong player
  - —cooperation: strong human player plays using machine
- to make long solution Tsume Shogi
  - —today only under-30-ply problems have been made
  - —challengeable
- to solve Shogi (to know which wins in initial position)
  - —totally impossible
  - —3x3 and 3x4 mini Shogis have been solved including Doubutsu Shogi(Animal Shogi)
  - —Even solving 55-Shogi (a 5x5 mini Shogi) is still too hard

Time flies like an arrow
and Fruit flies like an banana.
Shogi is a fruit fly in computer science,
mathematics, and artificial intelligence.

Some Shogi Problems

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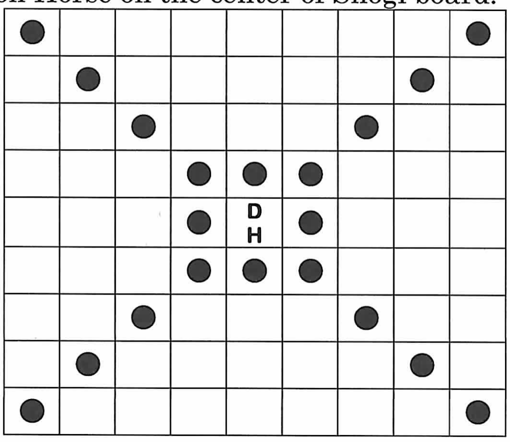
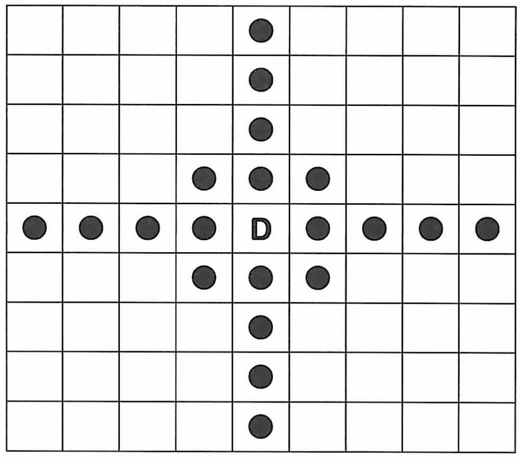
Peaceful Dragon Horses

Arrange 15 pieces of Dragon Horse (promoted bishop) on Shogi board which can move like bishop or king in chess such that no DH attacks other. The marks ● below show the squares of Dragon Horse on the center of Shogi board.



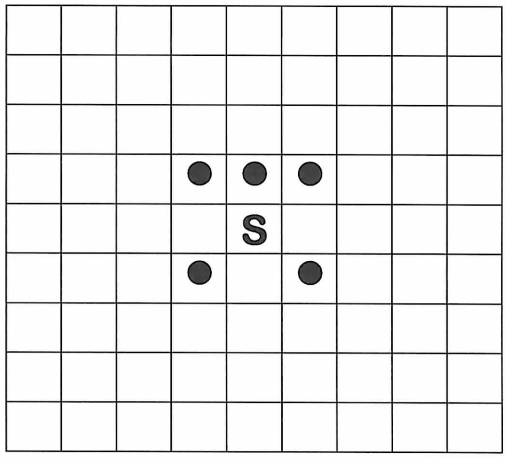
Dragon Covering

Arrange 6 pieces of Dragon (promoted rook) on Shogi board which can move like rook or king in chess such that all vacant squares are attacked by them. The marks ● below show the squares of Dragon on the center of Shogi board.



The Tour of Silver

Make a longest looping path by the piece Silver in Shogi board, where any square can be visited only once like the knight tour in chess. Then prove it is the longest. Silver can move to the marks ● as follows:



Academy of Recreational Mathematics Japan English Issure Membership Starts

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This is the first special issue of ARMJ news Journal in English language, and English issue membership, which is intended to activate interactive relationship between Japanese and oversea puzzlists. You will find what we 164 members of ARMJ are doing every month. We hope you join us. (Yoshiyuki Kotani, alpha@ba2.so-net.ne.jp)