Computer Chinese Chess

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Abstract

- **An introduction to problems and opportunities in Computer Chinese Chess.**
  - **Open game**
  - **Middle game**
  - **End game**
- **How to generate endgame databases efficiently?**
  - **Exhaustive enumeration.**
  - **Memory addressing space.**
  - **Speed.**
- **How to use endgame databases during searching?**

Introduction

- **Western chess programs.**
  - **One of the important areas since the dawn of computing research.**
  - **Pioneer paper by C.E. Shannon (1950).**
  - **Beat the human champion at 1997.**
  - **Many techniques can be used in computer Chinese chess programs.**
- **Computer Chinese chess programs.**
  - **About 7-dan.**
  - **Computing research history: more than 30 years late.**
    - ***Started at about 1981.***

Chess Related Researches

- **Chess related research:**
  - **Open game.**
    - *Many pseudo theories.*
    - *Heuristics.*
  - **Middle game searching.**
    - *Traditional game tree searching.*
  - **Endgame.**
    - *Databases.*
    - *More heuristics.*

Books about Chinese Chess

- **First written book: South Sung (about 1127–1279 AD)**

Properties of Chinese Chess

- **Several unique characteristics about Chinese chess.**
  - **The usage of Cannon.**
  - **Categories of defending and attacking pieces.**
  - **The positions of Pawns.**
  - **Complex Chinese chess rules.**
  - **Palace and the protection of kings.**
  - **Material combinations:**
    - ▷ *Although Knight is roughly equal to Cannon, Rook + Knight + Cannon is better than Rook + 2 Cannons.*
    - ▷ *Knowledge inferencing among material combinations [Chen et al. 2007].*

Research Opportunities

- **Some research opportunities.**
  - **Open game theories.**
    - ▷ ***Learning form a vast amount of prior human knowledge [Chen et al. 2006].***
  - **Much larger searching space:**
    - ▷ ***Western chess:*** 10^{123}
    - ▷ ***Chinese chess:*** 10^{150}
    - ▷ ***Deeper searching depth and longer game.***
  - **Game tree searching.**
    - ▷ ***The usage of materials.***
    - ▷ ***Knowledge inferencing among material combinations [Chen et al. 2007].***
  - **Endgame: contains lots of pieces.**
  - **Rules.**

Endgame Databases

- **Chinese chess endgame database:**
  - **Indexed by a sublist of pieces S, including both Kings.**

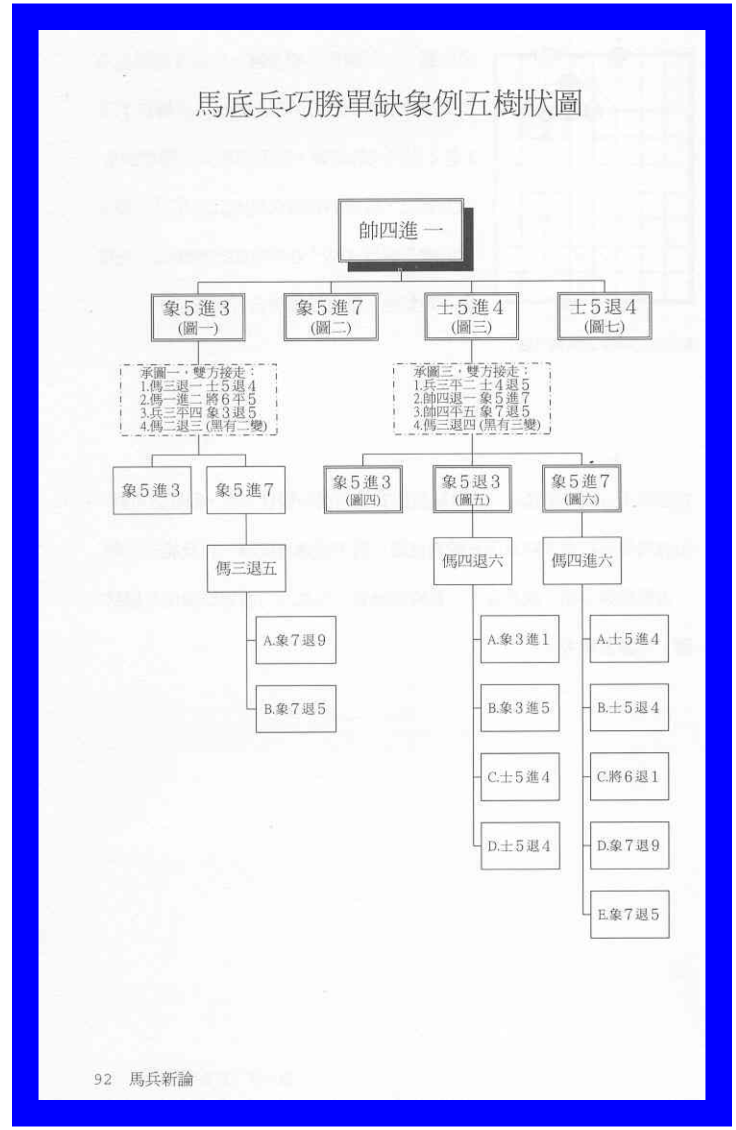
K	G	M	R	N	C	P
King	Guard	Minister	Rook	Knight	Cannon	Pawn
帥 將	仕 士	相 象	俥 車	傌 馬	炮 包	兵 卒

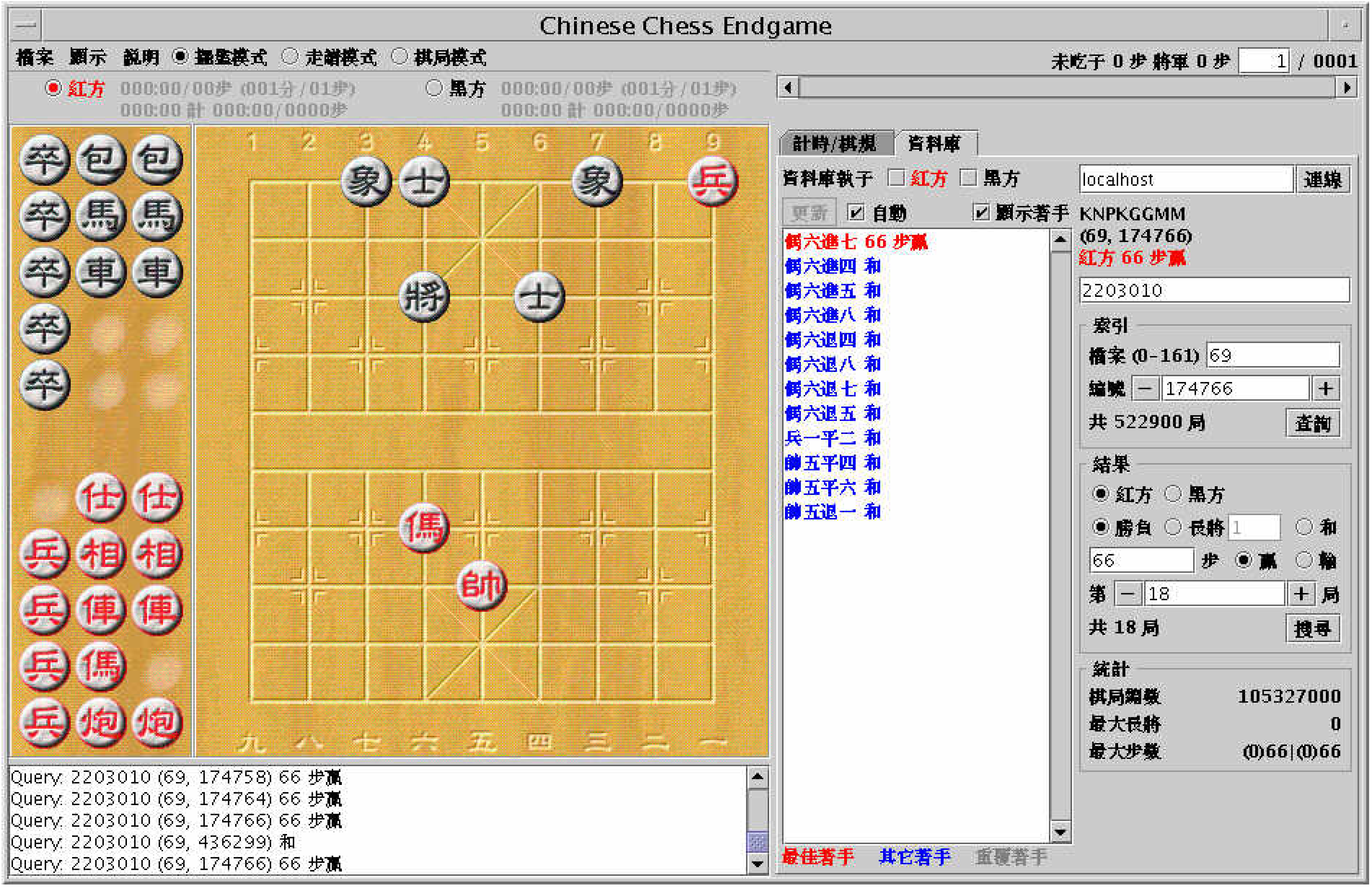
    - ▷ *KCPGGMMKGGMM (炮 兵 仕 仕 相 相 vs. 士 士 象 象): the database consisting of RED Cannon and Pawn, and Guards and Ministers from both sides.*
  - **A *position* in a database S: A legal arrangement of pieces in S on the board and an indication of who the next player is.**
  - ***Perfect information* of a position:**
    - ▷ *What is the best possible outcome, i.e. win/loss/draw, that the player can achieve starting from this position?*
    - ▷ *What is a strategy to achieve the best possible outcome?*
  - **Given S, to be able to give the perfect information of all *legal positions* formed by placing pieces in S on the board.**
  - ***Partial information* of a position:**
    - ▷ *win/loss/draw; DTC; DTZ; DTR.*

Usage of Endgame Databases

- **Improve the “skill” of Chinese chess computer programs.**
  - **KNPKGGMM (傌 兵 vs. 士 士 象 象)**
- **Educational:**
  - **Teach people to master endgames.**
- **Recreational.**

An Endgame Book




Chinese Chess Endgame
檔案 顯示 說明 編輯模式 走譜模式 棋局模式
未吃子 0 步 將軍 0 步 1 / 0001
紅方 000:00/00步 (001分/01步) 000:00 計 000:00/0000步
黑方 000:00/00步 (001分/01步) 000:00 計 000:00/0000步
1 2 3 4 5 6 7 8 9
九 八 七 六 五 四 三 二 一
計時/棋規
資料庫
資料庫執子 紅方 黑方
localhost
連線
更新 自動 顯示著手
KNPKGGMM
(69, 174766)
紅方 66 步贏
2203010
傌六進七 66 步贏
傌六進四 和
傌六進五 和
傌六進八 和
傌六退四 和
傌六退八 和
傌六退七 和
傌六退五 和
兵一平二 和
帥五平四 和
帥五平六 和
帥五退一 和
索引
檔案 (0-161) 69
編號 174766
共 522900 局
查詢
結果
紅方 黑方
勝負 長將 1 和
66 步 贏 輸
第 18 局
共 18 局
搜尋
統計
棋局總數 105327000
最大長將 0
最大步數 (0)66|(0)66
最佳著手 其它著手 重覆著手
Query: 2203010 (69, 174758) 66 步贏
Query: 2203010 (69, 174764) 66 步贏
Query: 2203010 (69, 174766) 66 步贏
Query: 2203010 (69, 436299) 和
Query: 2203010 (69, 174766) 66 步贏


Chinese Chess Endgame
檔案 顯示 說明 走譜模式 棋局模式
未吃子 0 步 將軍 0 步 1 / 0001
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紅方 和
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傌六進八 和
傌六退四 和
傌六退八 和
傌六退七 和
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棋局總數 105327000
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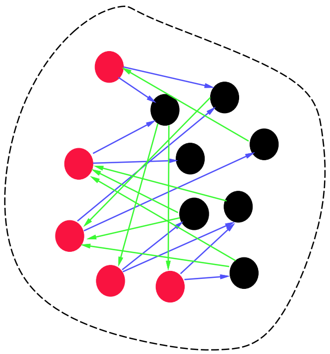
Query: 2203010 (69, 174764) 66 步贏
Query: 2203010 (69, 174766) 66 步贏
Query: 2203010 (69, 436299) 和
Query: 2203010 (69, 174766) 66 步贏
Query: 2203010 (69, 203899) 和

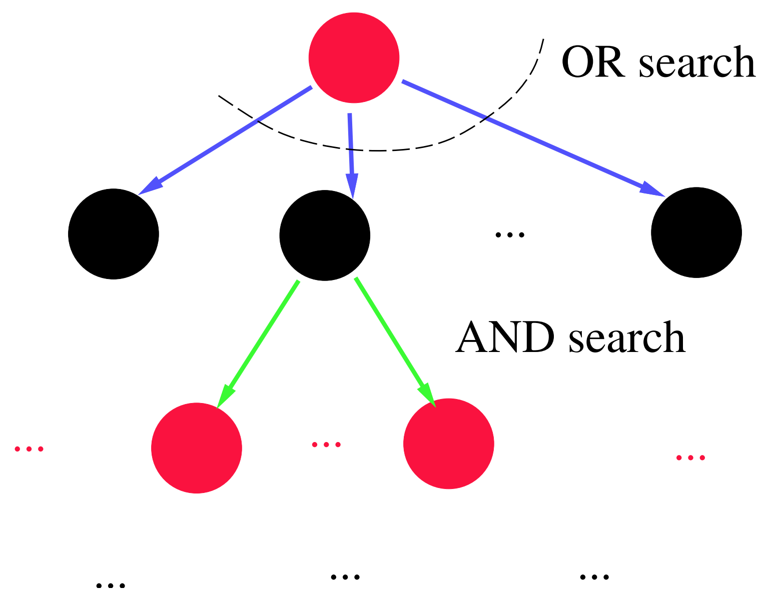
Definitions

- **State graph for an endgame H:**
  - **Vertex: each legal placement of pieces in H and the indication of who the current player (Red/Black) is.**
    - ▷ *Each vertex is called a* **position**.
    - ▷ *May want to remove symmetry positions.*
  - **Edge: directed, from a position x to a position y if x can reach y in one ply.**
  - **Characteristics:**
    - ▷ *Bipartite.*
    - ▷ *Huge number of vertices and edges for non-trivial endgames.*
    - ▷ *Example: KCPGGMMKGGMM has $1.5*10^{10}$ positions and about $3.2*10^{11}$ edges.*



Overview of Algorithms

- **Forward searching: doesn't work for non-trivial endgames.**
  - **AND-OR game tree search.**
  - **Need to search to the terminal positions to reach a conclusion.**
  - **Runs in exponential time not to mention the amount of main memory.**
  - **Heuristics: A*, transposition table, move ordering, iterative deepening . . .**

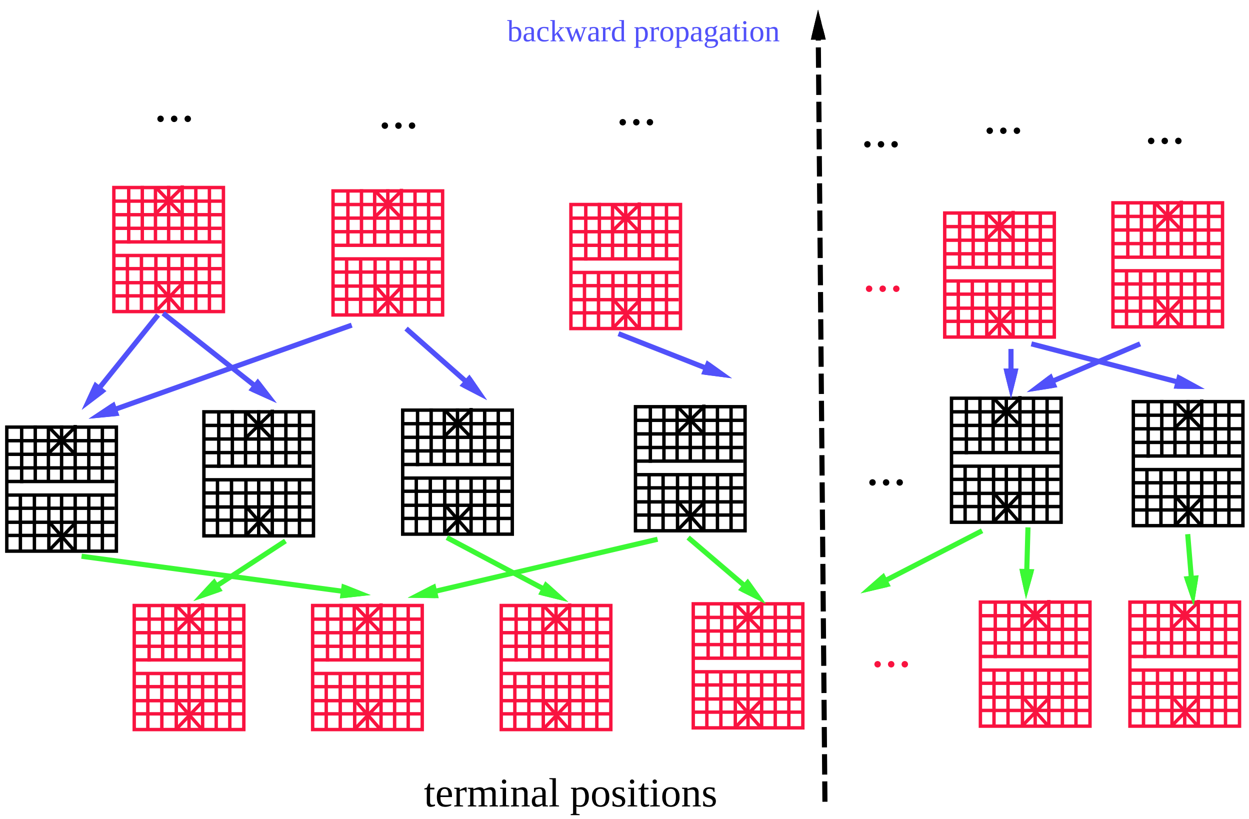


Retrograde Analysis (1/2)

- **First systematic studies by Ken Thompson 1986 for Western chess.**
- **Algorithm:**
  - **List all positions.**
  - **Find all positions that are initially "stable", i.e., solved.**
  - **Propagate the values of stable positions backward to the positions that can reach the stable positions in one ply.**
    - ▷ *Watch out the and-or rules.*
  - **Repeat this process until no more changes is found.**

Retrograde Analysis (2/2)

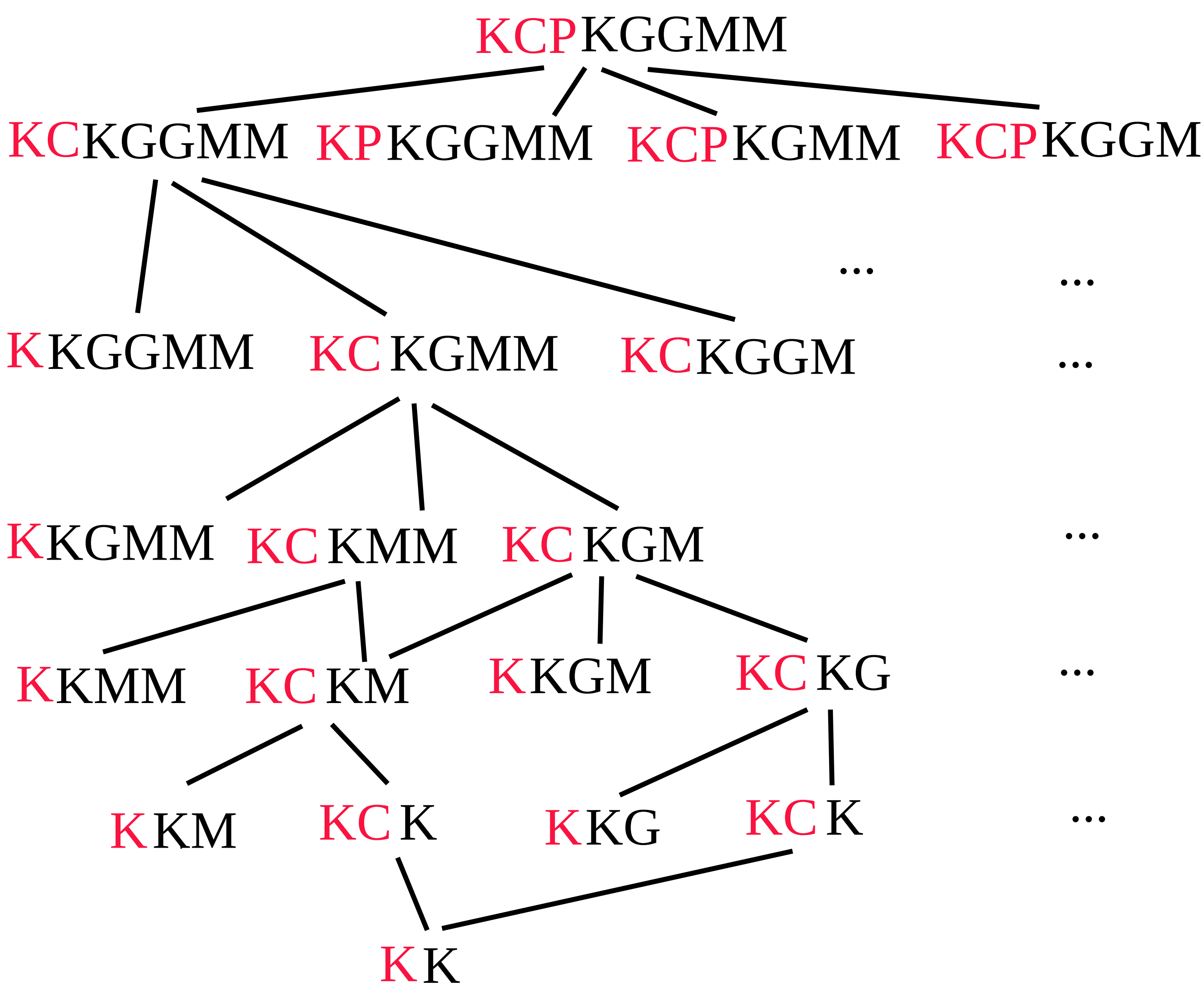
- **Critical issues: time and space trade off.**
  - **Information stored in each vertex can be compressed.**
  - **Store only vertices, generate the edges on demand.**
  - **Try not to propagate the same information.**



Stable Positions

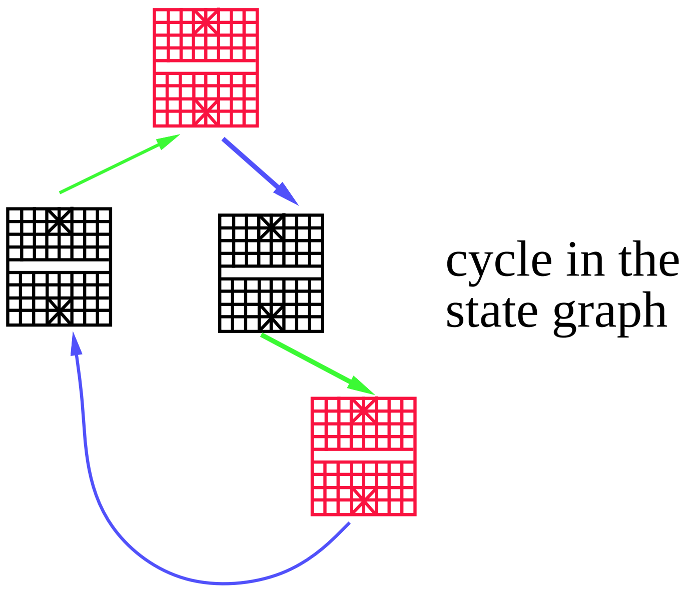
- **Another critical issue: how to find stable positions?**
  - **Checkmate, stalemate, King facing King.**
  - **It maybe the case the best move is to capture an opponent's piece and then win.**
    - ▷ ***so called "distance-to-capture" (DTC);***
    - ▷ ***the traditional metric is "distance-to-mate" (DTM).***
- **Need to access values of positions in other endgames. For example,**
  - **KCPKGGMM needs to access**
    - ▷ ***KCKGGMM***
    - ▷ ***KPKGGMM***
    - ▷ ***KCPKGMM, KCPKGGM***
  - **A lattice structure for endgame accesses.**
  - **Need to access lots of huge databases at the same time.**
- **[Hsu & Liu, 2002] uses a simple graph partitioning scheme to solve this problem with good practical results.**

An Example of the Lattice Structure



Cycles in the State Graph (1/2)

- **Yet another critical issue: cycles in the state graph.**
  - **Can never be stable.**
  - **In terms of graph theory,**
    - ▷ ***a stable position is a pendant in the current state graph;***
    - ▷ ***a propagated position is removed from the sate graph;***
    - ▷ ***no vertex in a cycle can be a pendant.***



Cycles in the State Graph (2/2)

- **For most games, a cyclic sequence of moves means draw.**
  - **Positions in cycles are stable.**
  - **Only need to propagate positions in cycles once.**
- **For Chinese chess, a cyclic sequence of moves can mean win/loss/draw.**
  - **Special cases: only one side has attacking pieces.**
    - ▷ *Threaten the opponent and fall into a repeated sequence is illegal.*
    - ▷ *You can threaten the opponent only if you have attacking pieces.*
    - ▷ *The stronger side does not need to threaten an opponent without attacking pieces.*
    - ▷ *All positions in cycles are draws.*
  - **General cases: very complicated.**

Previous Results — Retrograde Analysis

- **Western chess: general approach.**
  - **Complete 3- to 5-piece, pawn-less 6-piece endgames are built.**
  - **Selected 6-piece endgames, e.g., KQQKQP.**
    - ▷ *Roughly $7.75 * 10^9$ positions per endgame.*
    - ▷ *Perfect information.*
    - ▷ *1.5 $-$ 3 $*10^{12}$ bytes for all 3- to 6-piece endgames.*
- **Awari: machine and game dependent approach.**
  - **Solved in the year 2002.**
  - $2.04 * 10^{11}$ **positions in an endgame.**
    - ▷ *Using parallel machines.*
    - ▷ *Win/loss/draw.*
- **Checkers: game dependent approach.**
  - $1.7 * 10^{11}$ **positions in an endgame.**
    - ▷ *Currently the largest endgame database of any games using a sequential machine.*
    - ▷ *Win/loss/draw.*
- **Many other games.**

Results — Chinese Chess

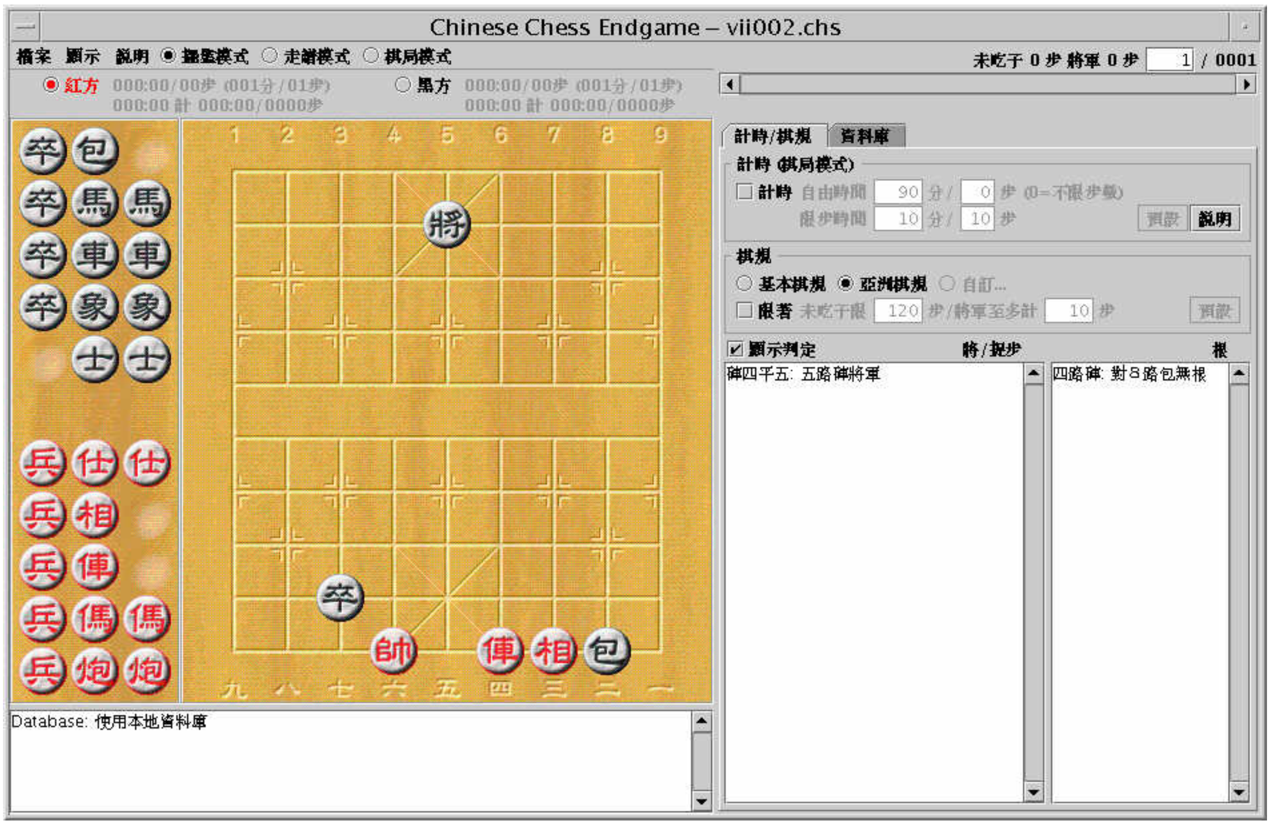
- **Earlier work by Prof. S. C. Hsu (許舜欽) and his students, and some other researchers in Taiwan.**
  - **KRKGGMM (俥 vs. 士 士 象 象) [Fang 1997; master thesis]**
    - ▷ ***About*** $4 * 10^6$ ***positions; Perfect information.***
- **Memory-efficient implementation: general approach.**
  - **KCPGMKGGMM (炮 兵 仕 相 vs. 士 士 象 象) [Wu & Beal 2001]**
    - ▷ ***About*** $2 * 10^9$ ***positions; Perfect information.***
  - **KCPGGMMKGGMM (炮 兵 仕 仕 相 相 vs. 士 士 象 象) [Wu, Liu & Hsu 2004]**
    - ▷ ***About*** $8.8 * 10^9$ ***positions;*** $2.6 * 10^{-5}$ ***seconds per position; Perfect information.***
    - ▷ ***The largest single endgame database and the largest collection reported.***
  - **Verification [Hsu & Liu 2002]**
- **Special rules: more likely to be affected when endgames get larger.**

Chinese Chess Special Rules (1/3)

- **A player cannot avoid the losing of the game or important pieces by forcing the opponent to do repeated counter-moves.**
  - **Checking the opponent's king repetitively with no hope of checkmate.**
    - *Asia rule example #2.*
  - **Chasing an unprotected opponent's piece repetitively with no hope of capturing it.**
    - *Asia rule example #19.*
  - **Threatening (to checkmate) repetitively with no hope of realizing the threat.**
    - *Asia rule example #31.*
- **Sometimes it is difficult to check whether a piece is *truly* or *falsely* protected.**
  - **Asia rule example #39.**
  - **Asia rule example #105.**
- **Not a problem for Western chess.**
  - **Cycles mean draw.**

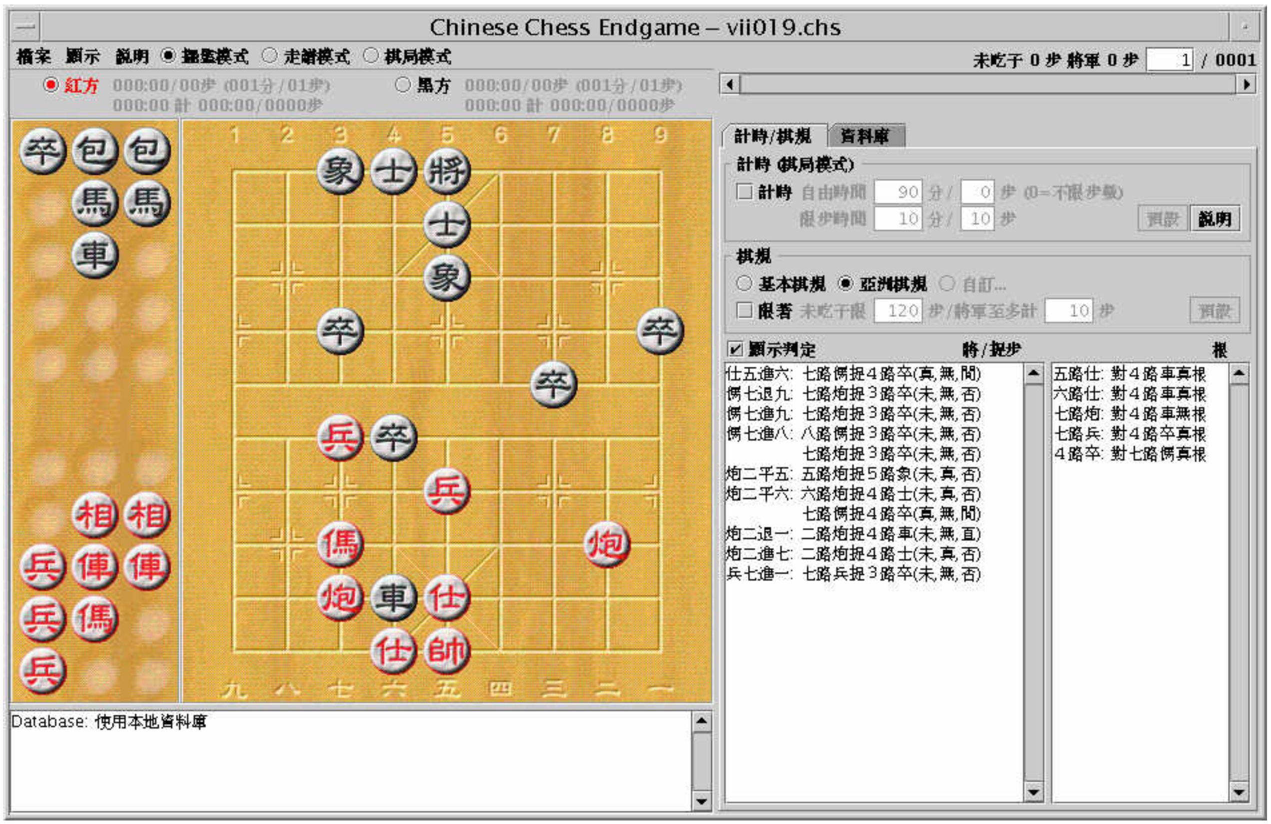
Asia Rule Example #2

- **Checking the opponent's king repetitively with no hope of checkmate.**
  - ▷ *R4=5,K5=6,R5=4,K6=5,...*
  - ▷ *Red Rook checks Black King.*



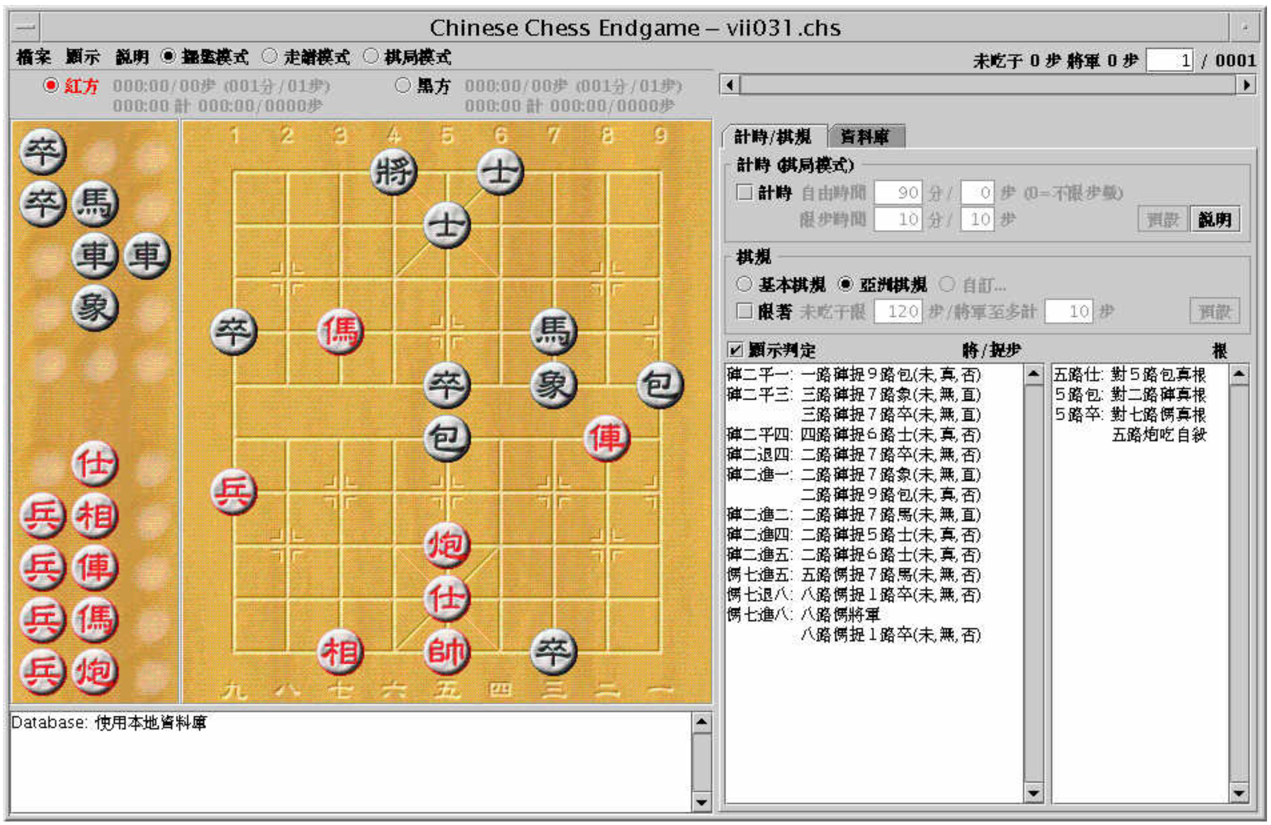
Asia Rule Example #19

- **Chasing an unprotected opponent's piece repetitively with no hope of capturing it.**
  - *C2−1,R4−2,C2+2,R4+2,...*
  - *Red Cannon at the 2nd column chases Black Rook.*



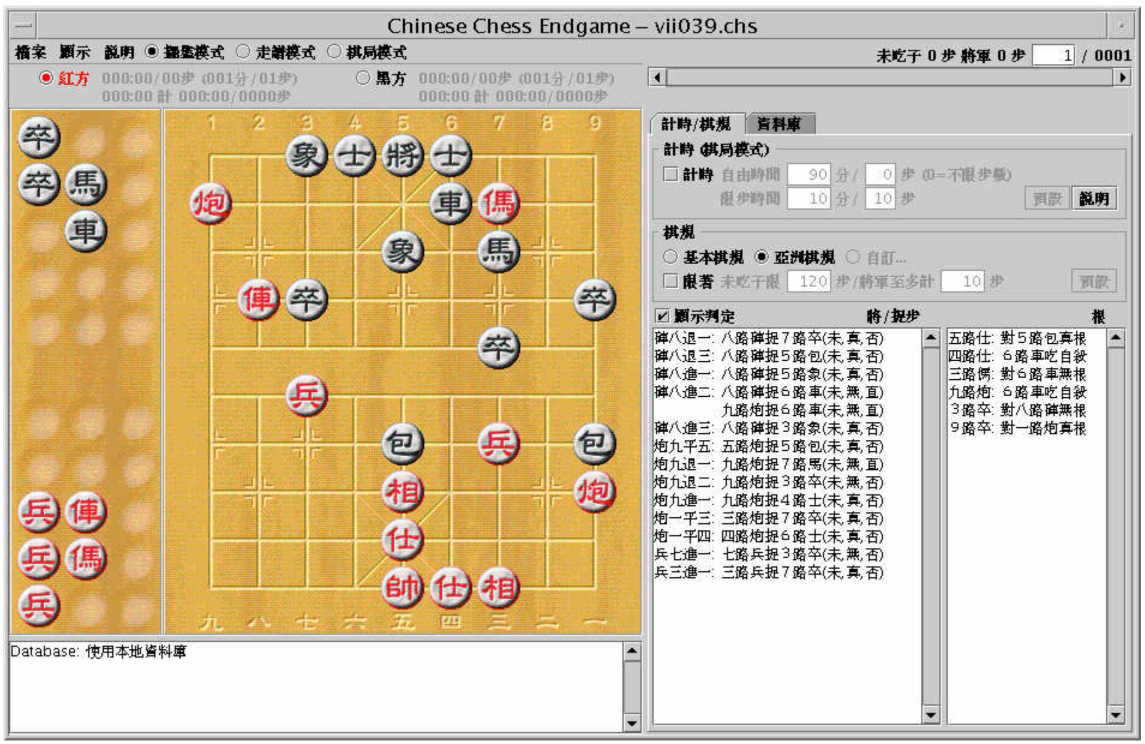
Asia Rule Example #31

- **Threatening (to checkmate) repetitively with no hope of realizing the threat.**
  - ▷ *R2=1,C9=8,R1=2,C8=9,...*
  - ▷ *Black Cannon at the 9th column threatens to checkmate.*



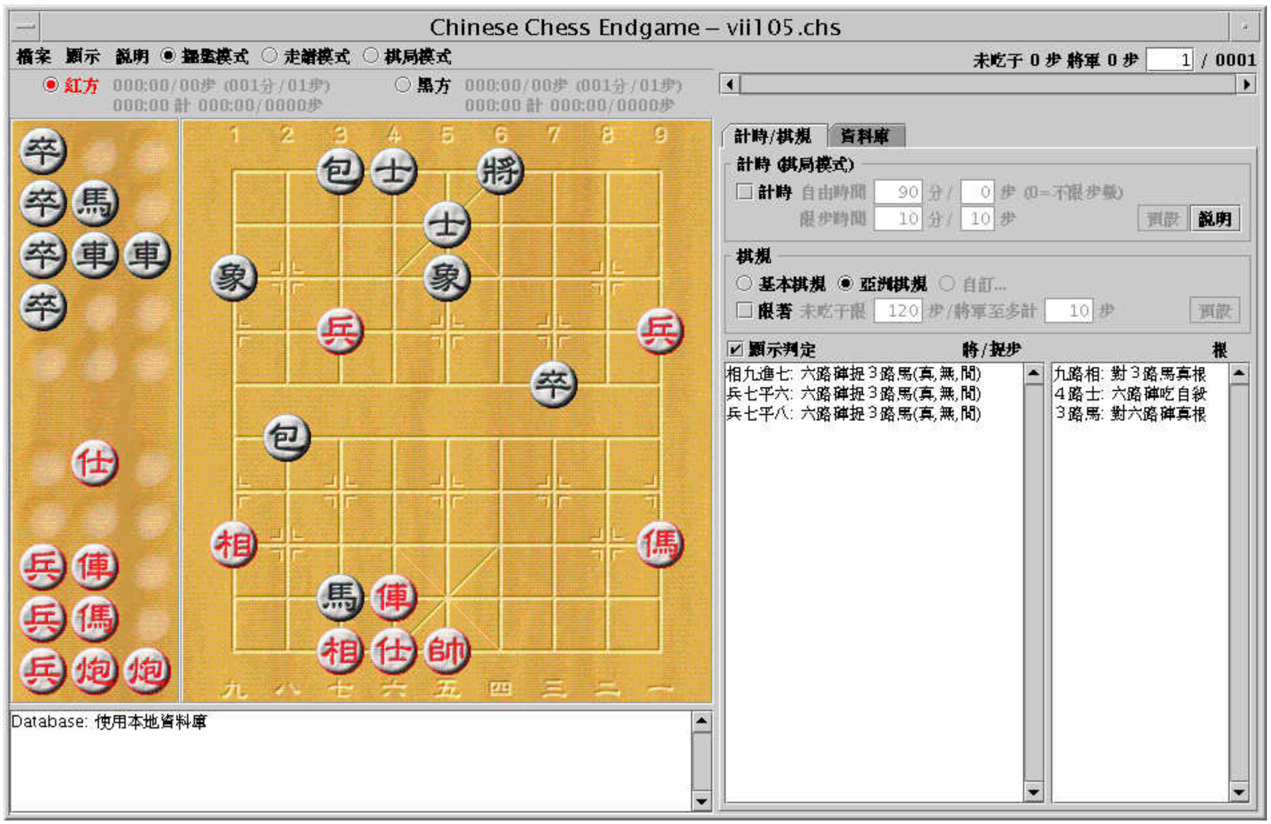
Asia Rule Example #39

- **Sometimes it is difficult to check whether a piece is *truly* or *falsely* protected: the definition of a protector is complicated.**
  - ▷ ***R8+2,G6+5,R8−3,G5−6,...***
  - ▷ ***Red Knight at the 2nd column is not protected.***
  - ▷ ***Black Rook at the 6th column cannot threaten.***



Asia Rule Example #105

- **Sometimes it is difficult to check whether a piece is** *truly* **or** *falsely* **protected: you can block a protector.**
  - ▷ *P7=6,M1+3,P6=7,M3−1,...*
  - ▷ *The protector of Black Knight at the 7th column is* **blocked.**

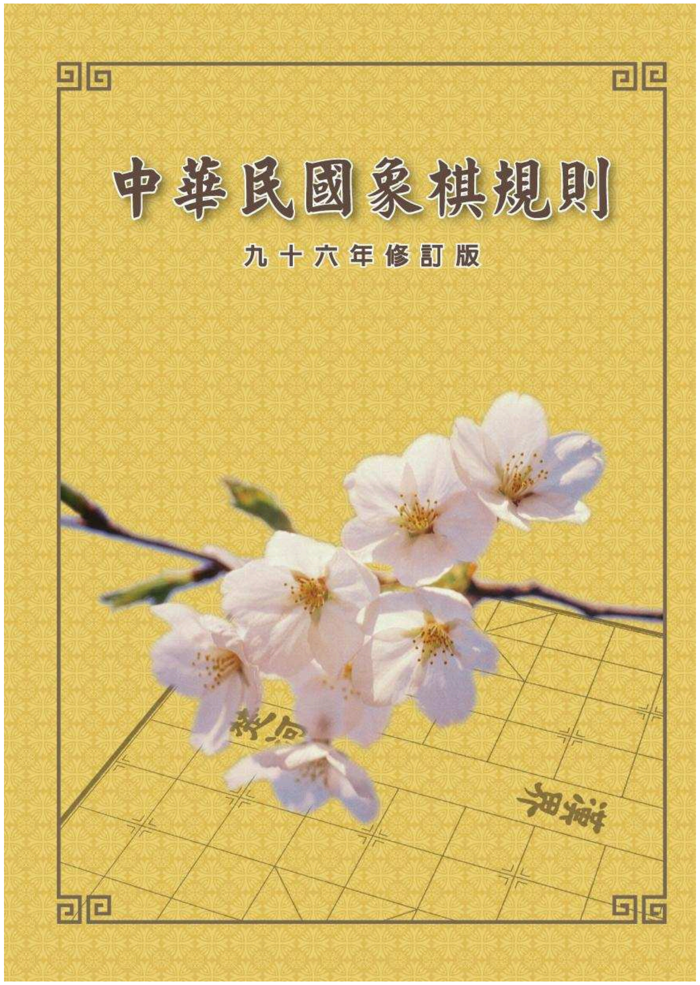


Chinese Chess Special Rules (2/3)

- **Two main categories:**
  - **Asian version (2003)**
    - *Supported by Asian Chinese Chess Association.*
    - *Simple and effective.*
    - *Is not really "fair" in certain complex cases.*
    - *Taiwan version (2007) is based on Asian version.*
  - **Mainland version (1999)**
    - *Supported by the PRC Chinese Chess Association.*
    - *A national standard.*
    - *Developing still in progress: latest version dated 1999.*
    - *Try to be as complete and "fair" as possible.*
- **Problems in computer implementation:**
  - **"Rules" are vague.**
  - **Often illustrated with examples.**

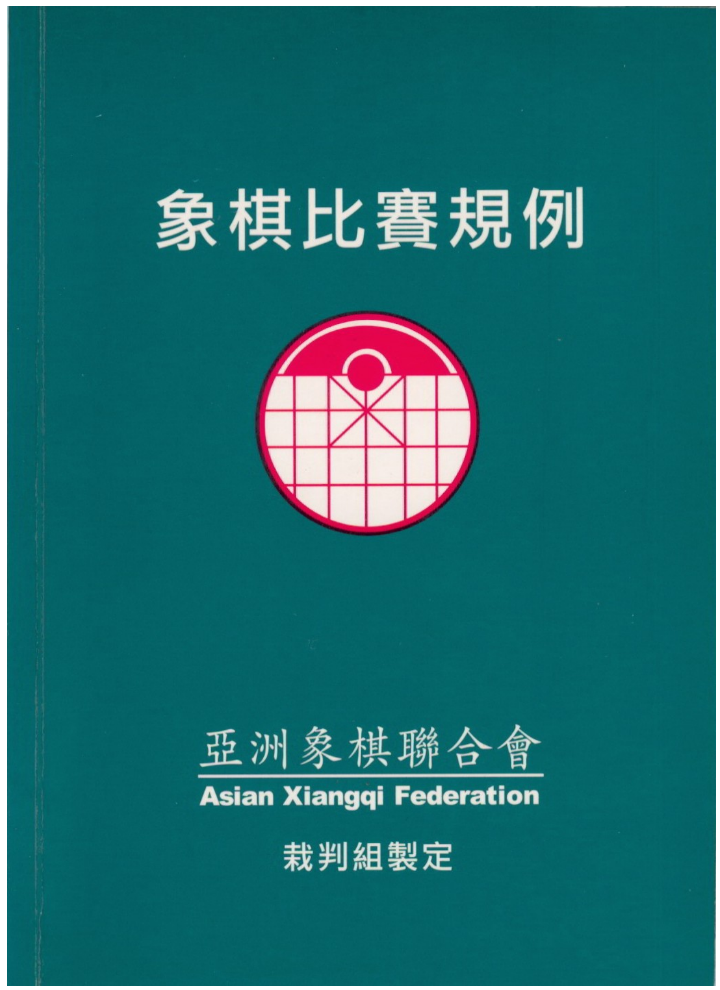
Rules: Taiwan Version

- **41 pages (2007).**



Rules: Asian Version

- **96 pages (2003).**



Rules: Mainland Version

- **329 pages (1999).**

Rules: Problems About the Mainland Version

- **317 pages (2000).**

Chinese Chess Special Rules (3/3)

- **Current treatment of special rules:**
  - **Avoid them at all: do not play repeated positions.**
    - ▷ *May lose advantage.*
    - ▷ *Must allow loops in endgame construction.*
  - **Special cases:**
    - ▷ *Only one side has attacking pieces: all are implemented.*
    - ▷ *One side has only a pawn and some defending pieces: can be affected by special rules.*
  - **Partial treatment:**
    - ▷ *Implement only the rules related to "checking."*
    - ▷ *Implement some "chasing" rules.*
    - ▷ *Verify whether special rules can affect an endgame.*
- **We need a throughout understanding of special rules to build larger endgame databases.**

Special Rules: Results

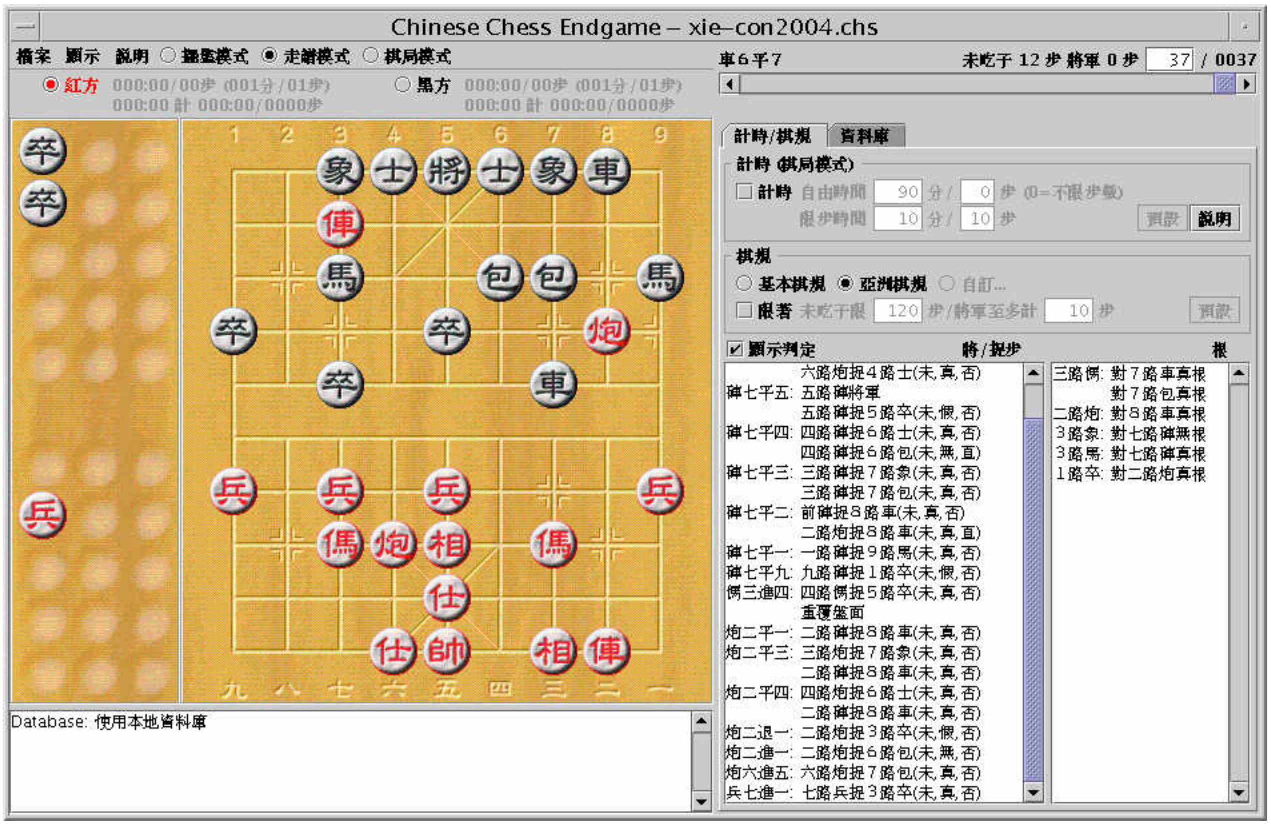
- **Partial treatment may build imperfect databases.**
  - [Fang, Hsu & Hsu 2000].
  - Upto 17.3% for the checking rule in KRKNMM (俥 vs. 馬 象 象) [Fang, Hsu & Hsu 2002].
  - Jih-tung Pai [Private communication 2003] implemented a variation of [Fang, Hsu & Hsu 2002].
- **Look for necessary conditions when databases can be stained by special rules.**
  - Selected 50+ databases are verified [Fang 2004].

Special Rules: Work in Progress

- **May affect the correctness of evaluation functions.**
  - **Xie Xie vs. Contemplation in the first WCCCC (Year 2004).**
    - *Less than 3 % of the games played.*
  - **About 5% of the games played in the 10th Computer Olympiad (October 2005) need to utilize special rules.**
- **Usage of logic and graph theory in an algorithmic context to describe the Asian version.**
  - **To explain all examples.**
  - **To abstract hidden experts' knowledge.**
  - **To obtain fast computer implementations.**
- **Still a long way to go for the Mainland version.**

Xie Xie vs. Contemplation at WCCCC 2004

- **Red: Contemplation.**
- **N3+4,R7−6,N4−3,R6−7,...**
  - ▷ *Red Knight at 3rd column is protected.*
  - ▷ *The game ended in a draw.*



Usage of Endgame Knowledge

- **Databases of endgames are too large to be loaded into the main memory due searching.**
- **Human experts:**
  - **Studies the degree of "advantageous" by considering only positions of pawns and material combinations.**
  - **Lots of endgame books exist.**
- **How to verify whether these knowledge are consistent?**
  - **Piece additive law: If endgame W is advantageous to the Red, then**
    - ▷ ***adding a red piece to W will never make it worse.***
    - ▷ ***deleting a red piece to W will never make it better.***
- **Inferencing the degree of "advantageous" of an unknown endgame W by values of endgames that we have already known.**
  - **[Chen et. al. 2008].**
- **Checking whether a set of endgame knowledge is consistent according to the piece additive law.**
  - **[Chen et. al. 2009].**

Concluding Remarks

- **Many open problems.**
- **Research opportunities:**
  - **Algorithm and complexity.**
  - **Algorithmic engineering.**
  - **External memory algorithms.**
  - **System implementation.**
  - **Parallel computing.**
  - **A.I.**
    - ▷ ***Knowledge extracting.***
    - ▷ ***Data mining.***
    - ▷ ...
  - **Discrete Math., e.g., Graph theory.**
- **Commercial opportunities.**
- **Fun.**

References and further readings

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