

# Design and Implementation of Magic Chess

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*Abstract:* Chinese dark chess is a stochastic game which is modified to a single-player puzzle game. We add some rules and reduce the board size. We also develop a computer program as a non-player character (NPC) to play with the player. The modified single-player game is called *Magic Chess*, which is suitable for the development of smartphone APPs. Many interesting rules are added in this paper. These rules are used for enhancing funny feeling and more difficulty level. Now there is more than 5 thousand times download Magic Chess app.

Keywords: App games, Chinese dark chess, stochastic games, magic chess, puzzle game.

## 1. Introduction

Chinese dark chess is a stochastic game. This game is famous in the Chinese culture sphere. Chinese dark chess is a two-player zero-sum stochastic game [2]. The board size is 4x8 squares. The kinds and quantities of the pieces used in Chinese dark chess are the same as those used in Chinese chess [3]. Chinese dark chess is as popular as Chinese chess in worldwide. In this paper, Chinese dark chess is modified to a single-player puzzle game. We add some rules and reduce the board size. We also develop a computer program as a non-player character (NPC) to play with the player. The modified single-player game is called *Magic Chess* [6], which is suitable for the development of smartphone APPs. This paper discusses the design of Magic Chess. Then, describes the used algorithms in this game. Finally, we propose the methods for adjusting the difficulties of the levels in the Magic Chess app.

## 2. Rules for Magic Chess

The rules of Magic chess are mainly modified from the game of Chinese dark chess. In Chinese dark chess, each of two players, called Red and Black, owns sixteen red and black pieces respectively. The sixteen pieces include one king, two guards, two ministers, two rooks, two knights, two cannons and five pawns. Each piece is in one of the two possible states that are revealed and unrevealed. When a piece is in the revealed state, the piece reveals its type and can be moved to another square. When a piece is in the unrevealed state, its type is unknown and the only allowed action on the piece is flipping that changes the state of the piece from unrevealed to revealed. All the pieces are placed face-down at the beginning of a game, meaning that they are

unrevealed. Two kinds of actions are allowed in the rules of Chinese dark chess: *flipping actions* and *moving actions*. Flipping actions are for face-down pieces, whose states are unrevealed. The detail rule of Chinese dark chess is described in [1][2].

The kinds of pieces used in Magic Chess are the same as those used in Chinese dark chess. One player, called Red, owns red pieces, and the other, called Black, owns black pieces. The sixteen pieces for each player include one king (K/k), guards (G/g), ministers (M/m), rooks (R/r), knights (N/n), cannons (C/c) and pawns (P/p), where the upper-case letters and the lower-case ones in the parentheses are for Red and Black, respectively. Table 1 shows the pieces.

Magic Chess uses small board sizes of 4x4, 5x5, and 6x6 to let players enjoy an interesting game in short time. Figure 1 shows the interfaces of 4x4 and 5x5 Magic Chess. Figure 2 is an example of 6x6 Magic Chess. **Table 2** shows the number of each kind of piece for different board sizes. Some levels use different combination of pieces to improve the flexibility. The player enters the next level only if he wins a game by means of either capturing all stones of NPC or letting NPC have no moves to play.

Table 1. The pieces.

Type of Pieces	king	guard	minis-ter	rook	knight	can-non	pawn
Red type	<b>K</b>	<b>G</b>	<b>M</b>	<b>R</b>	<b>N</b>	<b>C</b>	<b>P</b>
Chinese icon							
English icon							
Black type	<b>k</b>	<b>g</b>	<b>m</b>	<b>r</b>	<b>n</b>	<b>c</b>	<b>p</b>
Chinese icon							
English icon							
Rank	1 (high-est)	2	3	4	5	6	7 (low-est)

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Figure 1. 4x4 (left) and 5x5(right) Magic Chess.

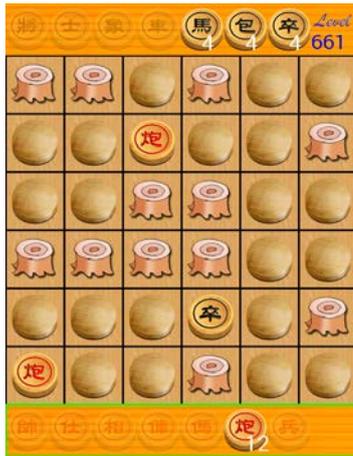


Figure 2. 6x6 Magic Chess.

Table 2. Piece sets for different board sizes.

Type of Pieces	king	guard	mini-ster	rook	knight	can-non	pawn	Wood <sup>4</sup>
#Pieces of 4x4	1	1	1	1	1	1	2	0
#Pieces of 5x5	1	1	2	2	2	2	2	1
#Pieces of 6x6	1	2	2	2	2	2	5	4

Players can only move pieces of their own colors. For pieces  $p$  other than cannons,  $p$  can be moved to an adjacent square  $s$ , which is one square up, down, left or right, if  $s$  is empty, or  $p$  can capture the opponent's piece  $p'$  at  $s$  when  $p$  has equal or higher rank than  $p'$ . The ranks of piece types are shown in Table 1. One exception is that pawns can capture the opponent's king, but not vice versa. A moving action is a *deterministic action*.

For cannons, the legal moving actions are different from those for other pieces. Cannons can be moved to an adjacent empty square in the same way as the actions applied on the other pieces, but cannot capture an adjacent opponent's piece. The only way for a cannon to capture an opponent's piece is to move the cannon

<sup>4</sup> The Wood is as in the center of the 5x5 board in Figure 1. Wood is a special piece. It does not belong to each side and cannot be captured by each side.

jumping over a *carriage* and then stay on the square with the opponent's piece to be captured. A carriage can be any unrevealed or revealed piece, but subject to three constraints:

1. The cannon, the carriage and the captured piece must be at the same row or the same column.
2. There are no pieces between the cannon and the carriage.
3. There are no pieces between the carriage and the piece to be captured.

The color each player owns is decided by the piece flipped by the first player at the beginning. That is, if the color of the first flipped piece is red, the first player is Red and the second player is Black, and vice versa.

The additional rules for Magic Chess are named *magic rules* are described as follows.

1. *Wood magic*: NPC could use this magic to change a player's piece to a *Wood*. Once a piece becomes a *Wood*, it will never restore.
2. *Ice magic*: NPC could use this magic to make a player's piece to an *Ice* with a number  $n$  (denoted by *Ice-n*). An *Ice* cannot be moved within  $n$  plies.
3. *Gold magic*: NPC could use this magic to make its own piece stronger. A piece protected by *Gold* magic can be captured only if the opponent plays capture moves twice on the piece.
4. *Hidden magic*: NPC could use this magic to let its own piece hidden after the piece is moved.

### 3. Algorithm for the NPC of Magic Chess

Monte-Carlo Tree Search is useful on stochastic games. [2] However, for NPC of Magic Chess developed as a smartphone APP, its search depth is limited by smartphone software and hardware. It is important to use a variety of methods to speed up and improve the capability of Magic Chess APP. The NPC uses *alpha-beta* search [5] and a transposition table to achieve the high performance objective. It also avoids a huge amount of repeated boards during the search to save time, and thus obtains satisfying results in most cases.

The evaluation function in alpha-beta search is calculated based on the following factors.

1. The total score of all alive pieces.
2. Strong pieces reachable distance from the player's weak pieces. In the other words, a minus score could be calculated in the case of weak pieces reachable distance to the player's strong pieces.
3. Combination with the revealing mechanism. We calculate the probability and expected value of each unrevealed piece.
4. A less number of winning moves is preferred.

### 4. Calculate of the Degree of a Level's Difficulty

It is important to control the degree of difficulty in a puzzle game. If a puzzle game is too difficult, the player may lose his patient; and if it is too easy, the player may feel boring. In this paper, we use the *win ratio* to

represent the degree of difficulty. The difficulty of most levels is between 0.2 and 0.5, and that of some key levels is between 0.1 and 0.2.

This section discusses how to calculate the degree of a level's difficulty. For example, the win ratios of level 100 and level 97 are 0.25 and 0.3 respectively. For the setting of each level, we simulate 1000 times and use the result to judge the difficulty of the level. The baseline is that the search depth set to 4. In this section, all the win ratios are respected to the simulated human player. Table 3 shows the win ratio for different search depth for a normal 4x4 Magic Chess. Table 4 shows the win ratio for changing a specific piece to a Wood.

Table 3. Win ratio for different search depths.

Search Depth	2	4	6
Baseline = 4	0.68	0.5	0.35

Table 4. Change a specific piece to a Wood.

Specific Piece	guard	Minister	rook	knight	cannon	pawn
Win Ratio	0.3	0.36	0.4	0.43	0.35	0.46

As mentioned in Section 2, NPC could use various magic on the player. The effects of Ice magic and Gold magic are shown in Table 5 and Table 6 respectively. Note that Ice- $n$  means a piece cannot be moved within  $n$  plies for  $n = 1, 2, 3$ . Table 7 shows the effect of the combination of magic.

Table 5. The effect of Ice magic for the player.

Ice magic	Ice-1	Ice-2	Ice-3
Baseline = 4	0.45	0.3	0.2

Table 6. Protect a specific NPC piece with Gold magic.

Specific Piece	guard	minister	rook	knight	cannon	pawn
Win Ratio	0.42	0.45	0.46	0.47	0.45	0.49

Table 7. The effect of the combination of magic.

Initial Game Board Status	Win Ratio
Change the player's one Pawn and one Cannon to a Wood and Ice-2, respectively	0.3
Change the player's one Guard and one Pawn to a Wood, respectively.	0.19
Change the player's one Guard, one Minister and one Cannon to a Wood, respectively.	0.15
Change the player's one Cannon and one Minister to a Wood and Ice-3, respectively.	0.16
All NPC's pieces are protected by Gold magic, such as the example in Figure 3	0.1

All NPC's pieces are protected by Gold magic, and remove one NPC's Minister.	0.2
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The board size is also an important factor of the difficulty. We use programs to estimate the average playing time of a game. Both sides set to complete a move in 3 seconds. Table 8 shows the average playing time of different board sizes for 100 games, respectively. Table 9 shows the difficulties of different board sizes.

Table 8. The average playing times of different board sizes.

Type of Pieces	The average playing time(seconds)
#Pieces of 4x4	55
#Pieces of 5x5	75
#Pieces of 6x6	125

Table 9. The Win Ratios of different board sizes.

Type of Pieces	The Win Ratio
#Pieces of 4x4	0.37
#Pieces of 5x5	0.35
#Pieces of 6x6	0.30



Figure 3. An example of all NPC's pieces are protected by Gold magic. The winning rate is 0.1.

As mentioned in section 2, the rule of cannon is different to other pieces. In fact, the cannon is a special piece. There is no similar kind of piece in western chess and Shogi. In Magic Chess, many interesting initial board are made by adding cannons. Figure 4-7 are examples.

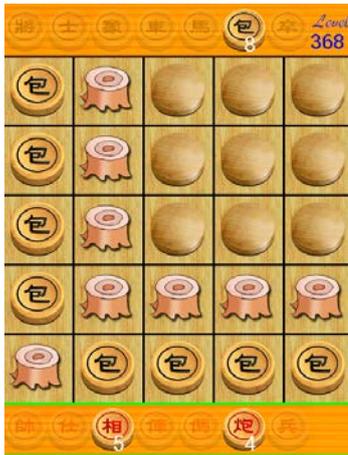


Figure 4. An example with many cannons. The winning rate is 0.15.

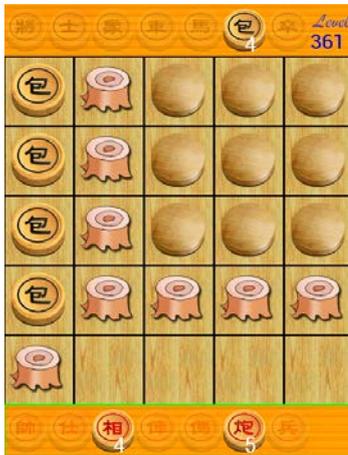


Figure 5. A many-cannons example. The winning rate is 0.65.



Figure 6. A many-cannons example. The winning rate is almost 0.



Figure 7. A many-cannons example. The winning rate is 0.05.

## 5. Conclusion

In this paper, we propose the game of Magic Chess as well as its rules and various magic. We also have created 690 levels of difficulty according to the simulation results. Magic Chess did a success in Taiwan APP market. In the future, the player can also use the magic. For example, the player could use Wood magic to make NPC's piece become a Wood. It will bring player more enjoyment. Furthermore, we utilize Facebook to make our APP more popular, that is, a player will get more bonuses by automatically posting messages to Facebook.

In order to make more non-Chinese people could play magic chess, we plan to revise Chinese dark chess symbol to cute pets which have food chain that could remove pet stones.

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