Ontology-based Intelligent Agent for Game of Go

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***Abstract*—This paper presents a developed ontology-based intelligent agent in Monte-Carlo Tree Search (MCTS) for the computer Go application. Unlike previous research, this paper employs features derived from professional Go players' domain knowledge to transform them into the opening-book sequence and represent them by a computer Go ontology. Afterward, the domain experts validate the built ontology. The developed computer Go ontology has been verified through the invited games for computer Go programs playing against human Go players. The results show that the ontology can work effectively for the intelligent agent and computer Go application.**

I. Introduction

Life is full of subjective judgments. Such judgments are personal opinions that have been influenced by one's personal views, experience, or background. They can also be interpreted as personal assessments of the levels of variables of interest. Regardless of the kind of information, there is uncertainty about it, and more often than not, the amount of the uncertainty can range from small to large [1]. Go is one of the most complex games. It is played regularly by millions of players in many countries around the world. Despite several decades of artificial intelligence, there are still no computer Go programs that can challenge a strong human player in 9×9 games [2]. This is because Go is a problem with high uncertainty, especially 19×19 board games. Each Go player has his own thinking way to play with his opponent, and each top professional Go player would take different strategies even though facing the same situation. Based on [2], the game of Go originates from China. Around the 7th century, the game was imported to Japan. In the late 16th century, the first westerner came into contact with Go. The game of Go is played by two players, Black and White, who consecutively place a stone of their color on an empty intersection of a square grid. Normally, the weaker player plays Black and starts the game. In the end, the player who controls most intersections of the board wins the game.

Computer Go has been developing for the past several years. Some of the world's top computer Go programs contain MoGo, Fuego, Zen, Many Faces of Go, CrazyStone, …, and etc. MoGo, Many Faces of Go, and Zen were the winners of 19×19 game in the 2007, 2008, and 2009 Computer Olympiad, respectively. Fuego was the winner of 9×9 game in the 2009 Computer Olympiad. CrazyStone came second in the 2007 Computer Olympiad. MoGoTW was developed based on MoGo 4.86 Sessions plus the Taiwan (TW) modifications developed jointly with the Taiwanese colleagues for a National Research Agency (ANR)-National Science Council (NSC) research project between France and Taiwan. In 1998, Martin Müller won despite 29 handicap stones against Many Faces of Go. In 2008, MoGo and CrazyStone won Myung-Wan Kim (8th Dan Pro and winner of the 2008 US Open) and Kaori Aoba (4th Dan Pro, 4P) in 19×19 games with handicap 9 and 7 stones, respectively. Since 2008, National University of Tainan (NUTN) in Taiwan and other academic organizations such as French National Institute for Research in Computer Science and Control (INRIA), Taiwanese Association for Artificial Intelligence (TAAI), and Academia Sinica, have co-hosted or co-organized or co-joined several Go-related events, including the 2008 Computational Intelligence Forum & World 9×9 Computer Go Championship (http://go.nutn.edu.tw/) [3], 2009 Invited Games for MoGo vs. Taiwan Professional Go Players (Taiwan Open 2009, http://go.nutn.edu.tw/2009/) [4], FUZZ-IEEE 2009: Panel, Invited Sessions, and Human vs. Computer Go Competition (http://oase.nutn.edu.tw/FUZZ_IEEE_2009/) [5], and 2010 Invited Game for MoGoTW vs. Human Go Player (http://go.nutn.edu.tw/2010/). The held events have widely reported by the several international mass media such as USA (http://www.ireport.com/docs/DOC-214010), Germany, France, Japan, and Taiwan. For recent years, MoGo has made a big improvement in both 9×9 and 19×19 games in 2009 [3], [4], [5].

In Feb. 2009, MoGo won with handicap 7 and 6 stones against Chun-Hsun Chou (9th Dan Pro and winner of the LG Cup 2007) and Li-Chen Chien (1st Dan Pro, 1P), respectively, in the Taiwan Open 2009 [4]. At the FUZZ-IEEE 2009: Panel, Invited Sessions, and Human vs. Computer Go Competition, held in Jeju Island, Korea, on Aug. 20-23, 2009, Taiwanese Go players were invited to play with four world's top computer Go programs, including MoGo, Fuego, Zen, and Many Faces of Go. In this event, Fuego won by 2.5 points as White against Chun-Hsun Chou in a 9×9 game [5]. In Oct. 2009, MoGoTW also won the first 9×9 game against top professional Go player (Chun-Hsun Chou) as Black (http://mogotw.nutn.edu.tw/chinese/result_20091026.htm). Therefore, computer Go Programs have won both as White and Black against top players. If the computer Go wins on a complete game like 4 out of 7 games with the top professional Go player, the computational intellignece of computer Go program will be completly done for 9×9 game of Go.

The 2010 Invited Game for MoGoTW vs. Human Go Player was held at NUTN, Taiwan on Mar. 21, 2010. The 24 invited Go players were from 8 to 13 years old. And, they were divided into three gropus according to their Go's dan grade, namely 1-Dan (1D), 2D, and 3D. Each group had eight children. MoGoTW won all of the games except one game against a 3D Go player. Desipte one lost game, MoGoTW was qualified to award three certificates, including 1D, 2D, and 3D level, at the Haifong Weiqi Academy on Apr. 2, 2010. Simultaneoulsy, after the MoGoTW awarding ceremony, four Go players (9P, 1P, 7D, and 6D) were invited to play against MoGoTW. In the end of the games, MoGoTW won 3 games out of total 7 games. If computers continue to improve at this rate, one more human stronghold may fall in front of machines in less than 5 years in 9×9 game. Afterwards, the development team of MoGo and MoGoTW will definitely continue to enhance the strength and improve the weakness of developing computer Go by learning more knowledge and strategies from professional Go players in the future.

In this paper, there are three Go players invited to give comments on the games. Ming-Chi Cheng was born in Taiwan in 1965 and went to Japan to learn Go when he got the scholarship of the Ing Chang-Ki Weichi Educational Foundation in 1978. He became a 1P and 7P professional Go player in 1982 and 1995, respectively, and returned to Taiwan to popularize the Go education at Tainan city in 2000. He is currently a President of the Tainan Go association. Ping-Chiang Chou is the younger brother of the 9P professional Go player, Chun-Hsun Chou. He became a 4P professional Go player in 2006, and came second in the 2nd Taiwan Yu-De Cup 10D Go Competition. Biing-Shiun Luoh is a 6D amateur Go player, and currently he is the member of a council of the Tainan Ming-Sheng Go Culture Association. The remainder of the paper is organized as follows. Section II describes a related work about the ontology and agent. Section III introduces the fuzzy ontology model for opening-book of Go. Section VI shows some experimental results and discussions. Finally, conclusions are drawn in Section V.

II. Related Work

Game provides competitive and dynamic environments that make ideal test beds for computational intelligence theories, architectures, and algorithms [16]. Go currently remains a massive challenge for the researches on artificial intelligence, especially the 19×19 game. However, Go has led to advances in knowledge representation with fuzzy ontology and MCTS techniques [16]. The purpose of this paper is to use the fuzzy ontology to represent the knowledge of the computer Go. For the past years, ontology has been defined by several researches, such as 1) Ontology is an explicit specification of a conceptualization and a formal specification of a shared conceptualization [6]; 2) Ontology is a good knowledge representation and communication model for intelligent agents [7]; 3) Ontology is a method of representing items of knowledge (ideas, facts, things) in a way that defines the relationships and classifications of concepts within a specified domain of knowledge [13]; and 4) Ontology has the ability to define a variety of useful relationships among items of knowledge, and to implement these relationships in software, that makes the ontology such as powerful gadget in the knowledge manager's toolkit [13].

The use of ontologies to provide interoperability among heterogeneous data sources has been applied in many domains, including medical information systems [8], news summarization [7], software engineering [9], [10], food recommendation [11], recruitment [12], architectures [15], and etc. For example, Lee, Wang, and Hagras [11] proposed a type-2 fuzzy ontology to apply to the knowledge representation in the field of personal diabetic-diet recommendation. Sanchez et al. [12] designed the ontological model to represent the knowledge of the recruitment domain and developed an intelligent web portal for recruitment. Liu et al. [15] applied an ontology-based approach to the architecture modeling process and defined the knowledge and semantic units for the ancient Chinese architecture domain. Lee et al. [7] presented a fuzzy ontology and applied it to news summarization based on the Chinese news of three weather events captured from Chinatimes website from 2002 to 2004.

In addition to ontology, the technologies of agent are also an important topic in this paper. Over the past decade, there has been a growing interest in utilizing intelligent agents in computer games and virtual environment [19]. For example, Fogel [17] developed an evolutionary entertainment with intelligent agents to control characters in intelligent board games and other software entertainment products. Quek et al. [18] presented an evolutionary framework to simulate and study the collective outcome of public goods provisioning in an agent-based model. Lees et al. [19] addressed a central issue for high level architecture (HLA)-based games to develop the HLA-compliant game agents. Acampora, Gaeta, and Loia [21] propose an exploring e-learning knowledge through ontological memetic agents. According to [14], 1) An agent physically distributes required knowledge to several locations; 2) An agent can model autonomous entities; 3) Agent-based systems can employ security mechanisms; 4) Agent technology has the ability to communicate and coordinate; 5) Agents can automatically discover and compose e-services; 6) Intelligent agents have deliberate, reactive, and flexible behaviors and can learn; and 7) An agent's autonomous, reactive, and flexible characteristics make agents ideal for implementing ambient intelligence applications.

Agent-based systems embedded into the ontology are increasing being applied in a wide range of areas. For example, the Multi-agent Systems Group (GruSMA) team designed and implemented a Healthcare Services multi-agent system to help doctors reduce error at each diagnostic and treatment stage [20]. Lee and Wang [9] developed an ontology model to represent the Capability Maturity Model Integration (CMMI) domain knowledge to effectively summarize the evaluation reports for the CMMI assessment. Orgun and Vu [8] proposed an electronic Medical Agent System (eMAGS) with an ontology based on a public health message standard to facilitate the follow of patient information across a whole healthcare organization. Lee, Wang, and Chen [10] also developed an ontology-based intelligent decision support agent to evaluate the performance of each project member to assist in introducing project monitoring and control process area of CMMI. Wang et al. [14] also proposed the ontology-based multi-agents to evaluate the diet health status based on the constructed common Taiwanese food ontology and the personal project ontology.

III. Fuzzy Ontology Model for Opening-Book of Go

The structure of constructing the ontology to express the knowledge of opening-book for game of Go is shown in Fig. 1. The first step is to invite Go players to play against computer Go programs via the Go-playing graphic interface such as Kiseido Go Server (KGS) or Go Graphical User Interface (GoGui). Once the game is started, the records of board games are stored by following the Smart-Go Format (SGF). The records of the Go games are stored into the SGF files repository. Then, the linguistic descriptions, including *very good* (*VG*) move, *good* (*G*) move, *uncertain* (*U*) move, *bad* (*B*) move, and *very bad* (*VB*) move, on each move and alternative branches are given by the invited Go players via MultiGo software or talking to the side assistant. Fig. 2 shows an example of the fuzzy sets for fuzzy variable *Move-Score* = {*VeryBad*, *Bad*, *Uncertain*, *Good*, *VeryGood*}, which indicates that there are five fuzzy sets, including *VeryBad*, *Bad*, *Uncertain*, *Good*, and *VeryGood*, to describe the score of the move.

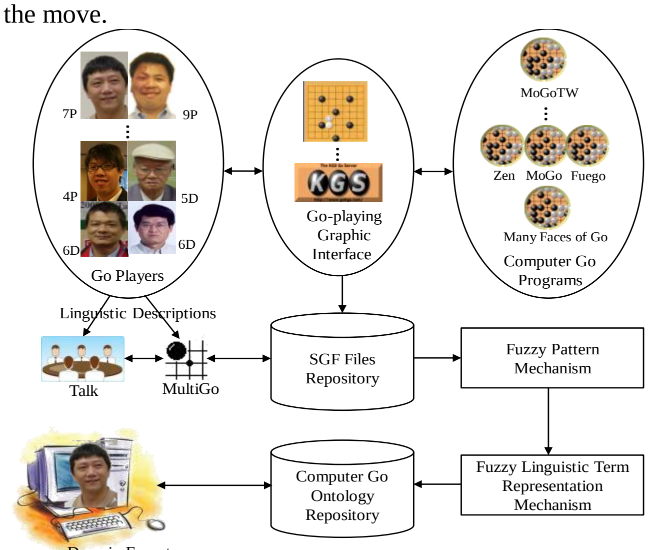


Fig. 1. Structure of constructing the ontology to express the knowledge of the game of Go.

The opening-book sequences are extracted based on the SGF files storing in the SGF files repository and obtained through the fuzzy pattern mechanism. The fuzzy pattern is used to present the opening-book sequence for the fuzzy ontology model. The total given patterns by Cheng is 8, including patterns 1–4 are for Black, and patterns 5–8 are for White. Each pattern has several branches to reflect parts of countless variations in Go. The details of the eight given patterns, but excluding some of the branches each move, are shown in Fig. 3. According to Cheng, Chou, and Luoh, Black 15 in Pattern 4 of Fig. 3 is a *VeryBad*, *VeryBad*, and *Bad* move, respectively, for Black. Another example is the pattern 5 in Fig. 3, according to Cheng and Chou, White 16 is a *Good* move. But, Luoh thinks of White 16 as a *VeryGood* move. Therefore, different experts have different meaning for the same move.

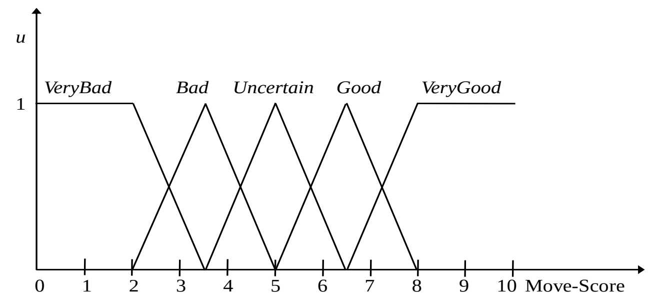


Fig. 2. Example of the fuzzy sets for fuzzy variable *Move-Score*.

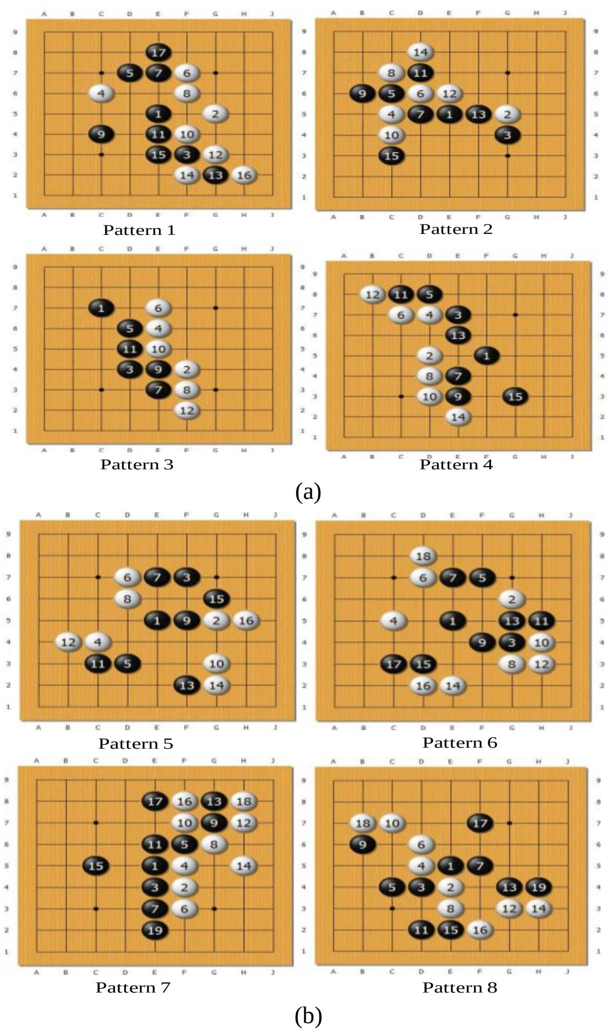


Fig. 3. Patterns given by Cheng, including (a) patterns 1–4 are for Black, and (b) patterns 5–8 are for White.

The fuzzy pattern template and one example of pattern 2 of the Fig. 3 are given in Table I, where *Fuzzy Linguistic Term* denotes the linguistic meaning of the fuzzy set described by various human Go players for the same fuzzy pattern or different fuzzy patterns. Table I indicates that the 7P Go player (Ming-Chi Cheng) considers B_{15} is an *Uncertain* move, but Chou and Luoh regard B_{15} as a *Good* and *VeryGood* move, respectively, which means that different Go players have different thinking and linguistic descriptions on the same pattern. The fuzzy linguistic term is used to represent the degree of goodness for each opening-book sequence via the fuzzy linguistic term representation mechanism. Different Go players maybe give different linguistic descriptions for the same opening-book sequence. Finally, the computer Go ontology can be built by integrating fuzzy pattern and fuzzy linguistic term, and the domain experts validate and verify the correctness of the constructed computer Go ontology.

TABLE I FUZZY PATTERN TEMPLATE AND GIVEN EXAMPLE

Fuzzy Pattern:

If B_1 *Locates* L_1 and W_2 *Locates* L_2 and … and B_{n-1} *Locates* L_{n-1} and W_n *Locates* L_n, and B_{n+1} *Locates* L_{n+1} **then** B_{n+1} is ***Fuzzy Linguistic Term*** Move

Given Example:

Go Player 1 (Ming-Chin Cheng, 7P)

If B_1 *Locates E5* and W_2 *Locates G5* and B_3 *Locates G4* and W_4 *Locates C5* and B_5 *Locates C6* and W_6 *Locates D6* and B_7 *Locates D5* and W_8 *Locates C7* and B_9 *Locates B6* and W_{10} *Locates C4* and B_{11} *Locates D7* and W_{12} *Locates E6* and B_{13} *Locates F5* and W_{14} *Locates D8* and B_{15} *Locates C3* **then** B_{15} is an ***Uncertain*** Move.

Go Player 2 (Ping-Chiang Chou, 4P)

If B_1 *Locates E5* and W_2 *Locates G5* and B_3 *Locates G4* and W_4 *Locates C5* and B_5 *Locates C6* and W_6 *Locates D6* and B_7 *Locates D5* and W_8 *Locates C7* and B_9 *Locates B6* and W_{10} *Locates C4* and B_{11} *Locates D7* and W_{12} *Locates E6* and B_{13} *Locates F5* and W_{14} *Locates D8* and B_{15} *Locates C3* **then** B_{15} is a ***Good*** Move.

Go Player 3 (Biing-Shiun Luoh, 6D)

If B_1 *Locates E5* and W_2 *Locates G5* and B_3 *Locates G4* and W_4 *Locates C5* and B_5 *Locates C6* and W_6 *Locates D6* and B_7 *Locates D5* and W_8 *Locates C7* and B_9 *Locates B6* and W_{10} *Locates C4* and B_{11} *Locates D7* and W_{12} *Locates E6* and B_{13} *Locates F5* and W_{14} *Locates D8* and B_{15} *Locates C3* **then** B_{15} is a ***VeryGood*** Move.

In Go, rank indicates a player's skill in the game. It is divided into two groups, i.e. amateur Go players and professional Go players. The rank for an amateur Go player could be 1st dan, 2nd dan, …., and 7th dan, where dan could be abbreviated "D." The player's skill increases from 1st dan (1D) to 7dan (7D)," For a professional dan grade, it is abbreviated "P," and the best rank is 9th dan (9P). According to the phases of Go, it is composed of three phases, namely an opening game, a middle game, and an end game. If the Go player, no matter a human or a computer Go, is able to do an excellent opening, the chances of winning will be great, especially playing such a small 9×9 board. As a result, it is very important for a computer Go to construct an excellent opening-book, if a computer Go would like to challenge the top human Go player. On the other hand, except for *VeryGood* moves and *Good* moves, the other types of moves, namely *Uncertain* move, *Bad* move, and *VeryBad* move, are also necessary to develop a computer Go assessment system in the future. However, the opening sequence varies with the stone's color that you hold. For this reason, the computer Go should exist two opening sequences, that is, one is as Black, and another is as White. If there is such an ontology existing to represent the above-mentioned information, then computer Go will quickly and easily learn and understand the opening sequences that are recommended by domain experts. Based on such ideas, Fig. 4 shows an illustrative example of the computer Go ontology as Black based on Pattern 4 of Fig. 3. The domain name is *Computer Go Ontology as Black*. The category is divided into *Professional Go Player* and *Amateur Go Player*. According to professional Go player's skill, it is rated from 1P, 2P, …, and 9P. Similarly, the skill of an amateur Go player is ranked from 1D, 2D, …, and 7D. Fig. 4 shows that each move played by Black is given a linguistic term by Cheng, Chou, and Luoh. For example, the comment on this sequence "F5 $\rightarrow$ D5 $\rightarrow$ E7 $\rightarrow$ D7 $\rightarrow$ D8" is a *VeryGood* move for both Cheng and Luoh; however, Chou considers this sequence is a *Uncertain* move. Additionally, the comment on B_1 (F5) is a *Good* move for Cheng, but it is an *Uncertain* move for Chou and a *Bad* move for Luoh.

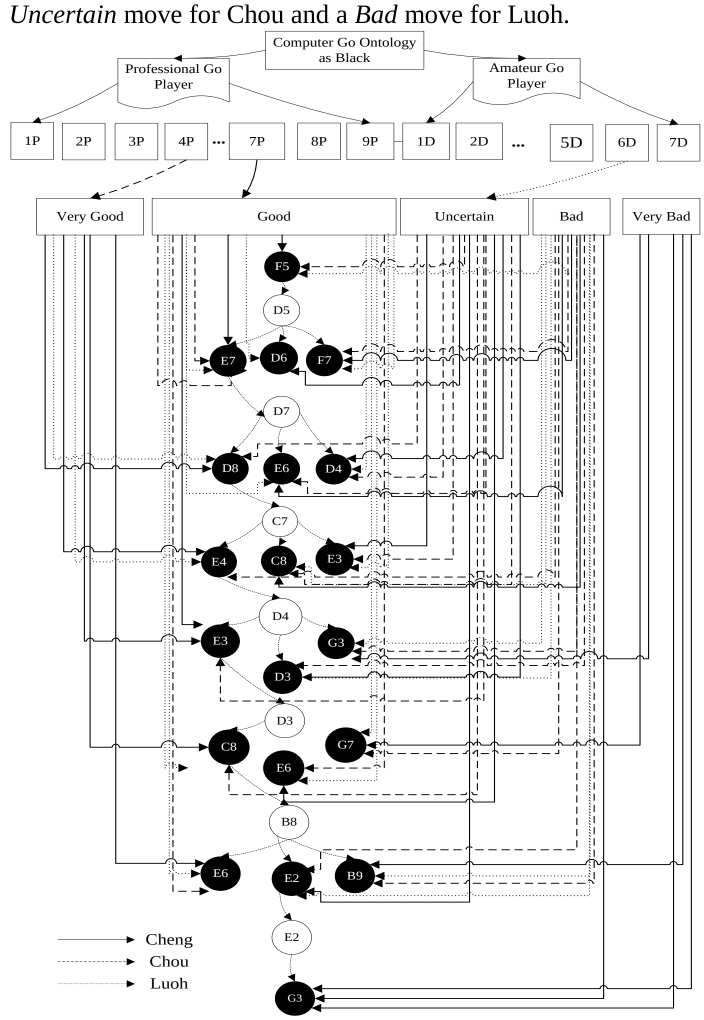
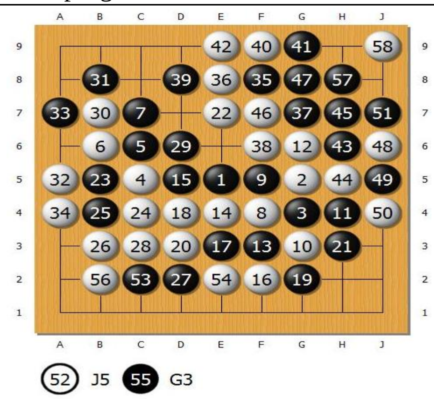


Fig. 4. Illustrative example of the computer Go ontology as Black.

IV. EXPERIMENTAL RESULTS

In this section, we show some results of the games at the event of the *2010 Invited Game for MoGoTW vs. Human Go Player*. This study constructed a platform for the Go games held at NUTN and Haifong Weiqi Academy, Taiwan, on Mar. 21 and Apr. 2, 2010, respectively. All games are 9×9 games, with komi 7.5 and 45 minutes per side. Additionally, all games follow the Chinese rule. On the invited games, *MoGo* or *MoGoTW* ran on four types of different machines, including a DELL PowerEdge R900 with 16 cores, NUTN-Mini-Cluster with 24cores, HP DL785G6 with 16cores, NUTN-Mini-Cluster with 16cores, and IBM x3850 with 8cores. Figs. 7–9 are the comments given by Ming-Chi Cheng on some of the games on Mar. 12 and Apr. 2. For more detailed information about the results, the authors can surf on the website–http://go.nutn.edu.tw/2010/result.htm.

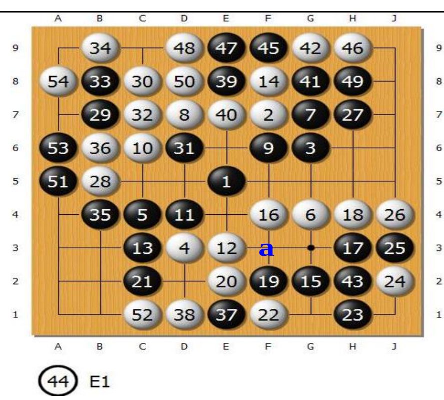


Results: MoGoTW (Black) vs. Chun-Hsu Chou (9P). White won by resignation.

Comments:

- White made a thorough counterattack with White 8 for Black 3, 5, and 7, which causes the game to be hopeless for Black.
- The opening sequence for Black 3, Black 5, and Black 7 should be improved in the future.

Fig. 7. Game 1.

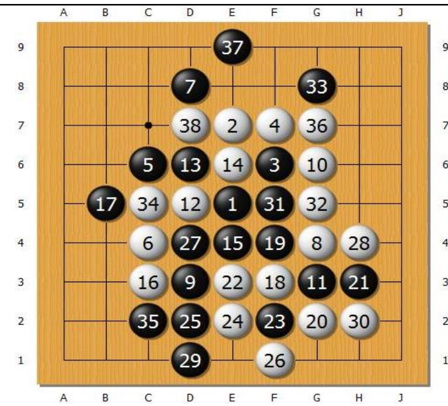


Results: MoGoTW (Black) vs. Yuan-Jung Chang (1P). White won by resignation.

Comments:

- The losing moves for Black are Black 7, 9, and 11. When playing until move 12, the groups of White stones on the upper-left and bottom-right corners are alive.
- Black 7, Black 9, and Black 11 are recommended to play at 16, 14, and at ‘a.’ In this way, Black might have the chance to win the game.

Fig. 8. Game 2.



Results: MoGoTW (White) vs. Shih-Min Chin (7D). White won by resignation.

Comments:

- Black 11 turned the game into a loss. If Black 11 played at 18, Black would simply win.
- White 6 is an uncertain move, and it would better if White 6 played at 22.
- White 8 is a good move.
- White 12, 14, 16, and 18 are the basis for White to win the game.
- After move 12, White plays very well.

Fig. 9. Game 3.

V. CONCLUSIONS

The advances in computational intelligence have contributed the computer Go to improve very much for the past years. It has revealed that MoGoTW has successfully got the 1D, 2D, and 3D certificates awarded by the Taiwanese Go association by winning 23 out of 24 games against 1–3D amateur Go players on Mar. 21, 2010. However, the game results indicate that MoGoTW still has the problem with the ko-fight and life-and-death, which means that it often turns MoGoTW into a loss. More research still needs to be done before the artificial intelligence completly solves 9×9 Go by winning 4 out of 7 games in the future, including integrating the type-2 fuzzy set to apply the proposed ontology to a computer Go program.

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