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Macroscopic Recognition and Decision Making for the GO Game Moves

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Abstract
In this paper, we proposed a new way to make a pre-pruned searching tree for GO game moves from macroscopic strategy described in linguistic expression. The strategy was a consequence of macroscopic recognition of GO game situations. The definitions of fuzzy macroscopic strategy, fuzzy tactics and tactical sequences using fuzzy set are shown and its family, so called "multi level fuzzy set". Some examples are also shown.
Keywords: Decision making in Game play, Fuzzy strategy, , computing with words

1. Introduction

In this paper, we propose a new way to make moves of GO game from fuzzy strategy described in a linguistic expression. The definitions of strategy, tactics and tactical sequences are defined using fuzzy set and its family, as multi level fuzzy set[2]. For linguistic descriptions we use fuzzy set theory that is powerful tool for describing complex systems[11, 12, 13].

Human beings have a great ability to solve complex problems which can not be handled by machines. The ability seems to be based on global view of human, or macroscopic recognition process high-level information processing. These ability can be described in natural language rather than in mathematical formulation.

1.1. Game of GO

This paper considered about GO game moves for an instance of complex problems.

The game of GO is a world wide famous board game, especially in the East Asia; Japan, Korea, and China. The aim of GO is to surround a larger territory with players' stones, which are colored white or black respectively. Its rule is quite simple, details are described in [1]. It has no probabilistic properties and no infinite state variable. In terms of Game Theory, it is called a finite state complete information 2 participants 0 sum game. Thus, it may has a optimal strategy , theoretically. However, its state space is too huge to give the concrete strategy using a logical way. Board situation is 3^{361} and size of search tree is approximately up to 10^{300}. Because chess is almost conquered by a computer, GO becomes a new target to AI technique test bench. There are numerous approaches, modeling local structure[4], memory based approaches [8] and so on. However, we don't know how to estimate the game situation by computational way and how to make a next move according to a situation. Thus computer GO systems are not so strong as them of chess. Now, we need to model the estimation process and making moves process of human beings, using linguistic approach dynamically, because they, i.e. modeling processes human thinking, are still "ill-defined problem" and linguistic terms may state them.

1.2. Macroscopic approach to make decision in GO Playing

On playing a game of GO, we, human beings play it with a macroscopic strategy expressed by natural languages. At every turn, We don't think about whole moves to search, but think about within the range of the tactical moves which realize the strategy and are concerned before.

GO game playing has a lot of points, which cannot be so much as defined well, to solve. They are called "ill-defined problems". GO problem is a good example of them. The reason why they can not be defined well is that these are open problems and it can not be defined in finite information in reasonable calculating time. If trying to define them absolutely, they have many properties depending on external situations even in the finite games like as GO game.

Human beings solve such an ill-defined problems using a macroscopic thinking. The search tree of problem has been constructed from macroscopic notion that have linguistic level meanings. In general a problem does not have an only goal but also several quasi-

Table 1. Basic Strategies, which are labels for fuzzy set on the tactical purposes space.

Connecting	Cutting	Escape
Survive	GetArea	ThreatenOpponent
DecreaseMoY.	IncreaseMoYo	

goals. The problem, therefore, can be solved using fuzzy search in which the linguistic model isn't so precise. Though it is called an approximate way, it has a suitable preciseness to solve the problem. We suppose that human beings use the linguistic information processing[3, 5], and realize it on a computer by means of fuzzy sets. They are also based on the concept of the computing with words[14].

Linguistic notion is used to solve complex problems in our daily life. For example, we make and use a procedure dynamically during serving a lunch, getting to a hotel, making a move for the game of GO or chess, driving a car and even proving mathematical theorem. Our information processing is strongly related to the approximate prediction made by knowledge. The key way to realize it is a framework of intelligent computing[9] using linguistic modeling approach[10].

Now, we propose a hierarchical structure which is descried by Multi-Leveled fuzzy set[2]. That is based on some observations on structures of a player's mental GO model. A player uses strategic notion to decide a next move in his mind. That move is a feasible realization of the strategy. In next section, it is shown how to decide a move from strategy, and that *Tactics* play a role of middle level notion, in the model.

It is also shown how to make searching tree from several move sequences that is generated by the way described above.

2. Generating canonical moves from Strategy

In many previous GO systems[6, 7], the "bottom-up" approach was used to choose a next move with evaluation of current situation of the board. It means a procedure, which analyses each point and give candidate moves independently each other. and select a move from them without correlation. This kind of procedures cause a unbalance result and rise collisions among rules giving candidate moves.

In these cases, however, Human beings may use a "top-down" approach to choose a next candidate move in looking ahead the board situation. They decide a macroscopic object, or a strategy represented by a linguistic term, for example terms in table 1, before analyzing the board situation in detail. They analyze the board and choose candidate moves with strategy. An interpretation method for linguistic strategy and its formula that makes it easy to interpret are needed, so that the "top-down" approach can be realized. The outline of the "top-down" procedure and expression of strategic notion are described below. In briefly its configuration is shown in Fig. 1.

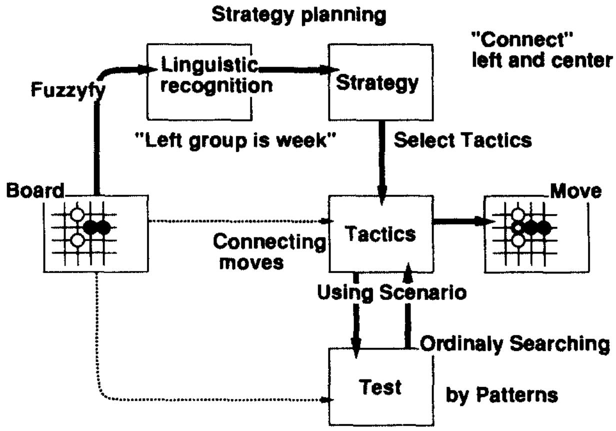

Figure 1. Top down GO playing system

In this paper, to simplify, *Strategy* is defined as a kind of restrictions, though we know it is a kind of mixed complicated notion of player's objects, the way to play, the way to prediction and etc. Suppose that the solution space is given by space of whole tactical moves, strategy is a restriction to give a subset of moves as solution, so that the subset can be called as strategy. In the real problems like the game of GO, tactics in the set of tactical moves is needed to realize the strategy related, and the set is a kind of fuzzy sets rather than crisp sets. Furthermore, tactics is also a fuzzy set of more concrete moves and/or move sequences. In the strategy leveled problems, it should be tested that these hierarchical fuzzy sets of notion are feasible. (See Fig. 2)

In this section, it is explained how important the "top-down" approach is in decision process of playing game of GO, first. Next, multileveled fuzzy sets are introduced for describing strategy and tactics, and the calculation method of hierarchical fuzzy notion is explained to realize "top-down" approach. For example, terms for tactics are limited in table 2,

the strategy can be defined with grade on space of tactics.

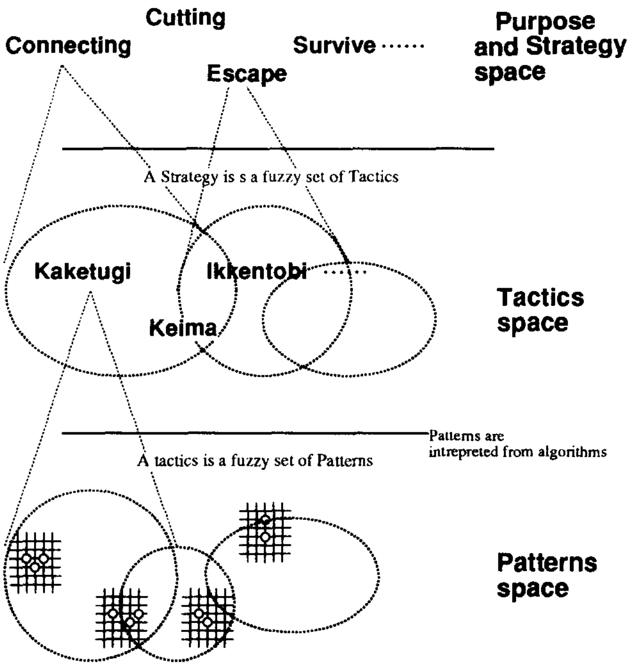

Figure 2. Hierarchical structure among strategy through moves

2.1. Deciding a move in Top-down

Because of some problems explained already above, top-down approach is needed to decide a move like as human beings do on the game of GO. Here is a top-down decision algorithm which determines a strategy first and gives a tactics and then gives a concrete move(s). The algorithm is as follows:
step 1) Recognizing the board situation roughly.
step 2) Deciding the Strategy
step 3) Determining several moves which realize the Strategy.
step 4) Applying the move determined in step above.
step 5) Evaluating new board situation after applying the move using evaluation criterion related to the Strategy in step 2

2.2. Description of Strategy and Tactics

Now, General strategy P play a simple one-oder decision tree to choice Basic strategic word S, In another words, creating fuzzy set of S,

a strategy P is a fuzzy set of basic strategy S. This

Table 2. Tactics , which are labels for fuzzy set on patterns space: in Japanese GO terms

Ate	Atekomi	Boushi	De
Fukurami	Guzumi	Hane	HasamiTuke
Hiki	Hiraki	Kake	Kakari
KataTugi	Keima	Kiri	Kosumi
Magari	Nobi	Nobikomi	Nozoki
Osae	Sagari	Shimari	Tobi
Tuke	Tukekoshi	Tume(Narrow)	Uchikomi(JampIn)
Warikomi	Wariuchi		

relation can be expressed in expression below.

$$P = \{g_{s_1}/S_1, g_{s_2}/S_2, , , g_{s_i}/S_i\} \quad (1)$$

Example) A fuzzy set of general strategy "Survive by making threaten to right side" is as follows:

$$\begin{array}{l}\{1.0/\text{"ThreatenOpponent"} \\ +0.8/\text{"GetArea"} \\ +0.6/\text{"Escape"} \\ +0.6/\text{"Connecting"}\}\end{array} \quad (2)$$

Each basic strategy S_j is defined as a fuzzy set of tactics T_i.

$$S_i = \{g_{t_1}/T_1, , , g_{t_j}/T_j\} \quad (3)$$

Example)

$$\begin{aligned}\text{"ThreatenOpponent"} &= \{1.0/KickOut \\ &+1.0/Blockade + 0.8/Isolate \\ &+0.7/KAKARI + 0.8/Narrow \\ &+0.7/JampIn\}\end{aligned} \quad (4)$$

A tactics T_j is a fuzzy set of static or sequential patterns (TESUJI in Japanese) M_i.

$$\begin{aligned}T_j &= \{g_{m_1}/M_1, , , g_{m_k}/M_k\} \\ &= \{g_{m_1}/a_1, , , g_{m_k}/a_k\} \\ &= \{g_{m_1}/(sequence_1), , , g_{m_k}/(sequence_k)\}\end{aligned} \quad (5)$$

Where, sequential patterns M_i are described by sequence generating algorithms(procedures) $a \in A$, which can be replaced with concrete move sequences ($sequence_i$) generated from itself.

Example)

$$\text{"}Blockade\text{"} = \{1.0/BOUSHI +0.9/KAKE + 0.6/MAGARI +0.8/TUKE + 0.8/TOBI +0.7/OSAE + 0.6/SOI +0.7/FUKURAMI\} \quad (6)$$

Now, they can be calculate. P1 and P2 can be combined using a fuzzy set operation like as an intersection.

2.3. Reduce the strategy into practical moves

These are mathematical defined notion of Multi-level fuzzy set. To use a decision process for a move of game of GO, P should be reduced into fuzzy set of S_i and T_j. There are a relation, as follows,

$$g_{s_i} = \mu_P(S_i), g_{s_i t_j} = \mu_{S_i}(T_j), g_{t_j m_k} = \mu_{T_j}(M_k) \quad (7)$$

$$\mu_P(T_j) = \max_i \min(\mu_P(S_i), \mu_{S_i}(T_j)) \quad (8)$$

$$\begin{aligned}\mu_P(M_k) &= \max_j \min(\mu_P(T_j), \mu_{T_j}(M_k)) \\ &= \max_{i,j} \min(\mu_P(S_i), \\ &\qquad \mu_{S_i}(T_j), \mu_{T_j}(M_k)) \quad (9)\end{aligned}$$

Example) Suppose these fuzzy set are given.
Strategy:

"threaten right group and Survive lower"

$$= \{0.8/MOYO + 1.0/SEME\}. \quad (10)$$

$$\text{"}MOYO\text{"} = \{1.0/Escape + 0.9/Blockade\}. \quad (11)$$

$$\text{"}SEME\text{"} = \{1.0/KickOut + 1.0/Blockade\}. \quad (12)$$

$$\text{"}Escape\text{"} = \{1.0/TOBI +0.9/KEIMA + 0.8/KOSUMI\}. \quad (13)$$

$$\text{"}Blockade\text{"} = \{1.0/BOUSHI +0.9/KAKE + 0.8/TOBI\}. \quad (14)$$

$$\text{"}KickOut\text{"} = \{1.0/NOBIKOMI +0.9/KOSUMITUKE + 0.9/SUBERI\}. \quad (15)$$

According to equation 8, Strategy: "threaten right group and bring up lower MOYO" can be transformed.

$$\begin{aligned}&\{0.8/MOYO + 1.0/SEME\} \\ =\ &\{0.8/\{1.0/UENIDERU + 0.9/Blockade\} \\ &+1.0/\{1.0/KickOut + 1.0/Blockade\}\}, \quad (16) \\ =\ &\{0.8/UENIDERU + 0.8/Blockade \\ &+1.0/KickOut + 1.0/Blockade\}, \quad (17) \\ =\ &\{0.8/UENIDERU + 1.0/KickOut \\ &+1.0/Blockade\}. \quad (18)\end{aligned}$$

According to equation (9),

$$\begin{aligned}eq.(18) =\ &\{0.8/UENIDERU + 1.0/KickOut \\ &+1.0/Blockade\} \quad (19) \\ =\ &\{0.8/\{1.0/TOBI + 0.9/KEIMA \\ &+0.8/KOSUMI\}1.0/\{1.0/NOBIKOMI \\ &+ +0.9/KOSUMITUKE + 0.9/SUBERI\} \\ &+ 1.0/\{1.0/BOUSHI + 0.9/KAKE \\ &+0.8/TOBI\}\} \quad (20) \\ =\ &\{0.8/TOBI + 0.8/KEIMA \\ &+0.8/KOSUMI + 1.0/NOBIKOMI \\ &+0.9/KOSUMITUKE + 0.9/SUBERI \\ &+ 1.0/BOUSHI + 0.9/KAKE \\ &+0.8/TOBI\} \quad (21) \\ =\ &\{1.0/NOBIKOMI + 1.0/BOUSHI \\ &+0.9/SUBERI + 0.9/KOSUMITUKE \\ &+0.9/KAKE + 0.8/TOBI \\ &+ 0.8/KOSUMI + 0.8/KEIMA\} \quad (22)\end{aligned}$$

In above case, NOBIKOMI and BOUSHI is chosen first, after that, SUBERI, KOSUMI and KAKE are tested later.

3. making tree from sequences

In this section, it is shown how to generate fuzzy sequences from a fuzzy set $\tilde{a}$ of the crisp algorithms , derived from eq. (9) and eq. (5), that gives macro sequences attached the current board situation, and then it also is shown how to make a weighted searching tree from several graded sequences. In addition, the fuzzy set $\tilde{a}$ is chosen, so that it represents moves according to given strategy. Thus, the evaluation of the final board can be based on the strategy. It makes the evaluation much simpler than it without any strategy, or purpose.

3.1. macro sequences made from algorithms

To give a sequences, there are two ways, 1) generate it by algorithms and 2) construct it up by each moves that are derived from strategies one by one. To realize the former way, formulation of fuzzy tactics on the set of crisp algorithms. The tactics fuzzy set is giving the dynamically Knowledges.

Assume that A is a set of crisp algorithms and B is a set of board situations. The crisp algorithm $a \in A$ gives sequence(s) $s \in S$ with a certain board situation $b \in B$. Now, Assume that a gives new board situation b' with b and gives a sequence s that change b into b', they are in formula as follows:

$$s = a \circ b \quad (23)$$

$$b' = s \bullet b, \quad (24)$$

where $\circ$ means affecting algorithm a to b, $\bullet$ means affecting sequence s to b and change it to b',

Now, we can extend and fuzzify eq. (23). Suppose $\tilde{a} \in A$ is a fuzzy set of algorithms and it can be described as,

$$\tilde{a} = \sum_{a_i \in A} \mu_{\tilde{a}}(a_i)/a_i. \quad (25)$$

Now,

$$\tilde{s} = \tilde{a} \circ b \quad (26)$$

$$\tilde{b}' = (\tilde{a} \circ b) \bullet b \quad (27)$$

can be as follows.

$$\tilde{s} = \sum_{a_i \in A} \mu_{\tilde{a}}(a_i)/(a_i \circ b) \quad (28)$$

$$\tilde{b}' = \sum_{a_i \in A} \mu_{\tilde{a}}(a_i)/((a_i \circ b) \bullet b) \quad (29)$$

3.2. Making searching tree from sequences

Once the graded searching tree is given, the system can search and choose best move in next tern. In this section, how to make a graded tree from several sequences.

Whenever that two sequences $seq_1 = (m_1^1, \cdots, m_i^1)$ and $seq_2 = (m_1^2, \cdots, m_j^2)$ are given and they have same subsequence $(m_1, \cdots, m_k), k < i, k < j$ at their head, they can be merged into one searching tree, and these sequences have grade of possibility g_1 and g_2 respectively.

The new tree merged can be represented as

$$(m_1, \cdots, m_k, \\ g_1/(m_{k+1}^1, \cdots, m_i^1), \\ g_2/(m_{k+1}^2, \cdots, m_j^2)) \quad (30)$$

Thus, add up the next tree in it. The new tree to merge have grade g_3.

$$g_3/(m_1, \cdots, m_k, m_{k+1}^1, \cdots, m_l^1, m_{l+1}^3, \cdots, m_n^3) \quad (31)$$

The tree completed to merge is as below.

$$(m_1, \cdots, m_k, \\ \min(g_1, g_3)/(m_{k+1}^1, \cdots, m_l^1, \\ g_1/(m_{l+1}^1, \cdots, m_i^1), \\ g_3/(m_{l+1}^3, \cdots, m_i^3)), \\ g_2/(m_{k+1}^2, \cdots, m_j^2)). \quad (32)$$

Now, it can be treated as a weighted searching tree of which branches have grade respectively and it could be searched by ordinary way to choose the best node in the tree.

3.3. Counter strategy

The moves by opponent are needed to make searching tree. This is a matter on another level from them explained above. In this case, the opponent's strategy is also needed, to generate opponent's move using same way for self. The most critical responses called counter strategy is concerned, here.

The most effective counter strategy can be chosen , because of presence of his strategy. In this paper, a relation R is introduced to represent the relation between his strategy $s_s \in S$ and opponent's strategy

Then, the relation R can be described on the direct product of S that is a set of strategy.

$$R \subset S \times S. \quad (33)$$

The opponent's strategy s_o can be described as,

$$s_o = R \circ s_s. \quad (34)$$

Both s_s, s_o are fuzzy sets. The example of relation R is shown in table 3 partially.

4. Concluding Remarks

We have shown how to describe strategy on the space of tactics with linguistic notion, how to treat them and how to make searching tree from graded macro sequences. In determining the counter purposes, it is shown that fuzzy relations realize the process generating counter purposes with linguistic terms.

In generally, facing to solve a complex problem, linguistic based information processing models are needed because of its ability to describe problem roughly. In

counter strategy	strategy		
	Increase MoYo	GetArea	Threaten Opponent
IncreaseMoYo	0.8	1.0	0.0
GetArea	1.0	0.8	0.8
ThreatenOpponent	0.8	0.8	0.0

Table 3. Fuzzy relation of the counter strategy

many situations complex problems should be described by linguistic terms, since we introduce a linguistic computing into a definition and a process of the strategy and the tactics of GO game by means of fuzzy set theory.

The parameters of these examples shown here isn't optimality nor feasibility, though their parameters are given by the results of quite few statistical experiments.

Thus, as a further work, We try to give a fuzzy set definitions of them similar conceptual fuzzy sets by automatically from game data.

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