Strategic Evaluation in Complex Domains

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Abstract
In some complex domains, like the game of Go, evaluating a position is not simple. In other games, like Chess for example, material balance gives good and fast to compute insight on the value of a position. In Go all the stones have the same value, so material balance is not a good heuristic. To evaluate a Go position, a computer needs a lot of knowledge and much more time. Evaluation in computer Go is interesting from an AI point of view, because it shows the power of knowledge in complex and real world domains.

Introduction
Evaluation functions are usually quite simple and fast. The simplicity of evaluations functions enables to concentrate on the search algorithm, and to replace the knowledge used by humans to solve problems by intensive search. Many researchers have recognized that there is a search vs. knowledge tradeoff [Michie 1977] [Berliner & al. 1990] [Junghans & Schaeffer 1997]. However in some domains like the game of Go, simple, fast and good evaluation functions do not exist (or at least have not been found despite a lot of efforts). Evaluating positions in such domains requires some times and a lot of knowledge. These domains are interesting for AI because they show the power of knowledge over brute force. They enable to devise, test and compare AI techniques related to the acquisition, learning, management and use of different types of knowledge [Pitrat 1990]. Finding a way to use knowledge so as to be efficient in these complex domains will also advance the state of the art of domains where search is important by improving search with knowledge. This is a more general approach to problem solving, this is the one humans use [McCarthy 1997].

In the first part we present the interest of the game of Go from an AI point of view. Then, we present our method to evaluate positions. In the following part, we show our this evaluation is integrated into a Go playing program.
the strategic part involved in Go programs and managed relations between groups with fuzzy status. [Cazenave & Moneret 1997] gives a method to develop strategic plans in situations involving uncertainty.

**Evaluating a position**

Strategic knowledge in games is about long term goals. In games such as Chess and Go, the high number of possible moves makes it impossible to forecast in the long term the consequences of the moves played. A solution to this problem is to have a gradual achievement of long term goals. It enables to know if a move makes the goal easier or harder to achieve. There are mainly two ways of managing a complex situation, breaking the problem into subproblems and relax the problem by defining a gradual achievement of it.

![Figure 1](image1)

This is particularly true for the strategy in the game of Go. The ultimate goal of a player is to make live the more stone on the board. However, in the middle game, most of the groups of stones (a group of stones is a set of stones of the same color which cannot be disconnected, stones of the same group have the same number in Figure 1) are in an uncertain state, and the evolution of this state cannot be precisely foreseen. It is very useful in such a case to have a gradual evaluation of their states and of the evolution of this state when playing different moves.

A friend intersections of a group is an empty intersection that can be connected to the group whatever the opponent plays, moreover, this empty intersection must not be connectable to a living opponent group.

![Figure 2](image2)

In Figure 2, the white friend intersections are filled with a small white point. The black friend intersections are filled with a small black point. The intersections that can be connected both to a white and a black group are filled with a small gray point. Each group owns a set of friend intersections of its own color.

The number of friend intersections of a group is a very good heuristic to approximate the degree of life of a group. For example, the group marked with 2 in Figure 2 has more than twelve friend intersections, it will therefore have no problems to live. Whereas the group marked with 3 in Figure 2 has only 7 friend intersections, it is not completely alive and may have some problems. Its degree of life is around 0.5. Two rules define the degree of life of a group given its number of friend intersections:

\[
\text{Degree}_\text{of} \text{life} (N, G, F) :- \\
\text{Number}_\text{of} \text{friend} \text{intersections} (N, G, H), \\
H > 3, \\
F_1 = (H - 3)/9, \\
F = \min(F_1, 1.0).
\]

\[
\text{Degree}_\text{of} \text{life} (N, G, F) :- \\
\text{Number}_\text{of} \text{friend} \text{intersections} (N, G, H), \\
H < 4, \\
F = 0.0.
\]

After these rules have been fired, one rule chooses the greatest of all the degrees of life.

The gradual degree of life is given by the real number \( F \), the group is represented by the variable \( G \), and the integer \( N \) is the number of moves to play to achieve this degree of life. The Figure 3 gives the graphical representation of the gradual achievement defined by the rules above.

![Figure 3](image3)

Many predicates contributes to the final goal of the
game: having more living stones than the opponent. These contributions are more or less graduals. They are represented in Figure 4. The vertical axis always represents the degree of life of the group, between 0 and 1.

![Graphs](image)

Figure 4

Table 2 gives an evaluation of the attributes for the four groups of Figure 1.

<table>
<thead>
<tr>
<th>Attributes/Groups</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of won life bases</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of unsettled life bases</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of won eyes</td>
<td>0.33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of unsettled eyes</td>
<td>0.16</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of friend intersections</td>
<td>0</td>
<td>1</td>
<td>0.44</td>
<td>0.8</td>
</tr>
<tr>
<td>Number of connections to living</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>friends</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2

Table 3 gives the degrees of life corresponding to each attribute for each group and also gives the final degree of life for the groups.

<table>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3

The strategic evaluation function in a Go playing program

![Diagram](image)

Figure 5

Our Go playing program is named Gogol. It develops AND/OR tree searches to calculate the states of tactical games. Each tactical game corresponds to a simple subgoal of the game of Go. The tactical games status are used to create the groups and to fill the predicates used by the strategic module. Gogol develops approximately 1000 proof tree searches on a position. It develops trees using Proof Number Search [Allis & al. 1994b], the result of a tree is a tactical theorem that applies to the board at hand: the moves advised by the theorem always reach the tactical goal used during the search. These proof trees contain between 2 and 600 nodes. Once the tactical results are deduced, the program fires the strategic evaluation rules that evaluate the degree of life of each group and its evolution after each interesting move. This information is used to choose the best move. The best move is chosen by evaluating the difference of the board value after and before each move. The best move is the move that has the highest difference.

To evaluate the value of the board, the system has to evaluate the degree of life and the importance of each group. The importance of a group is the evaluation of the difference of points at the end of the game between the life of the group and its death. It is computed using the following rule:

\[
\text{Value} (G, N) : - \\
\text{Number of stone} (G, N1), \\
\text{Number of friend intersections} (G, N2), \\
\text{Number of shared friend intersections} (G, N3), \\
N = N1 + N1 + N2 + N3.
\]

<table>
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<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of the group</td>
<td>24</td>
<td>80</td>
<td>32</td>
<td>31</td>
</tr>
</tbody>
</table>
When the values and the degrees of life of the groups have been computed, the system can evaluate a Go board:

\[
\text{Evaluation} = \sum (\text{Degree}_i \times \text{Value}) - \sum (\text{Degree}_j \times \text{Value})
\]

with \(i \in \text{Friends Groups}\) and \(j \in \text{Opponent Groups}\).

In the example of Figure 2, if black is the friend color, the evaluation of the position gives:

\[
\text{Evaluation} = 0.5 \times 23 + 0.44 \times 32 - 1.0 \times 80 - 1.0 \times 31 = -85.4
\]

This evaluation means that black is probably going to lose the game by 43 points. This analysis is compatible with the analysis of Go expert players. This evaluation function has been tested on numerous Go boards and it gives a good approximation of the evaluation of a position.

The two moves we are examining in the board of Figure 6 are the black moves at i28 and i59. Table 4 gives the outcomes of the black move at i28 and Table 5 gives the outcomes of the black move at i59.

If the board is evaluated after the two black moves, there is a variation of +12 points for the black move at i28 and a variation of +11 points for the black move at i59. The system will choose the black move at i28.

### Results

The best Go programs are those that have the best strategic evaluation function and the most precise tactical search engines. But it takes time to evaluate position, because for each strategic position evaluation, a lot of tactical searches have to be performed. So Go programs cannot search very deep at the strategic level. The precision of the evaluation function is therefore very important. It is based on a good knowledge of what are the important concepts of the game of Go (such as territory, influence, groups and their degrees of life).

Gogol plays a move in 10 seconds on a Pentium 133 MHz. It has participated in the 1997 FOST cup held during IJCAI97. It has finished 6 out of 40 participants. The five first programs are commercial programs.

Future work is to use learning, as described in [Cazenave 1996], at the strategic level. The goal of learning will be to improve the evaluation of positions and to find strategic moves interesting to try.

### Conclusion

Evaluation in computer Go is interesting from an AI point of view, because it shows the power of knowledge in complex and real world domains. In the search versus knowledge tradeoff, the game of Go is the one that has the most important knowledge component. We have shown how a complex evaluation function can be devised by breaking the problem into subproblems and relaxing the goals by making them gradual. This approach has been used to write the evaluation function of a Go playing program. It has shown its usefulness during the last FOST cup [Fotland 1997], an international competition between Go programs.

### References


