ICONCHESS: An Interactive CONsultant for CHESS Middlegames

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1   Introduction

Ever since Shannon [Shannon 50] published his proposal for a chess playing program, most programs have followed the brute force approach to chess, which relies on searching a large number of possible chess positions in order to produce a move that is appropriate for a given chess position. Programs that have dominated the computer chess scene through the years, such as those described in [Marsland et al. 90], rely primarily on fast search-based algorithms and/or special purpose chess hardware rather than on an intensive application of knowledge. A few systems have used a knowledge-based approach to deal with chess positions. Unfortunately, these programs [Wilkins 80], [Pitrat 77] have been able to deal only with very limited subsets of the game. The problem of teaching chess has also been rarely explored. In addition to the canned tutorials found with several commercial chess programs, the intelligent tutoring system UMRAO [Gadwal 90], and the Chessmaster's natural language advisor, while limited, are perhaps the most representative examples of the application of artificial intelligence (AI) techniques for teaching chess. Despite the limited effort in this direction, cognitive psychology research suggests the importance of different factors, such as inexact pattern recognition [De Groot 78], [Newell et al. 72], and high-level knowledge [Cooke et al. 93] which have been successfully handled by AI techniques, such as case-based reasoning (CBR) [Schank 89], and fuzzy logic in the creation of learning environments in other fields, [Schank et al. 94], [Edelson 92], [McNeill et al. 94]. ICONCHESS combines some of these techniques in a learning environment for chess middlegames.

2   ICONCHESS: A General View

The main purpose of ICONCHESS is to provide high-level advice about chess middlegame positions. This paper highlights some of the main features of ICONCHESS, a complete description can be found in [Lazzeri 95]. From the user's point of view, ICONCHESS is capable of doing the following main high-level tasks: 1) Analyze a chess position, extracting its relevant features. This analysis is particularly targeted to chess middlegame positions, even though it might be applied to other types of positions. Furthermore, it is expected that players with a moderate level of skill will benefit the most from this analysis. 2) Evaluate a chess position and suggest possible strategies for each side in terms of the relevant features of the position. 3) Retrieve similar positions from the knowledge base in order to obtain additional advice. 4) Present the analysis to the player using a graphical approach, by highlighting relevant squares in a chess diagram, or a textual approach, by giving brief textual explanations of the most relevant features of a position.

[Fig. 1] presents the information flow through the system. ICONCHESS has two main components, an EXPERT, used to compile all the knowledge relevant to a specific position, and a CONSULTANT, used to present this information to the student in the most appropriate format. Furthermore, several knowledge bases are required in order to generate the advice. These knowledge bases take different forms, such as case bases, rule bases, and fuzzy tables, as illustrated in [Fig. 1]; they will be explained in detail in subsequent sections.

A typical session with ICONCHESS is started by the user providing the ORIGINAL POSITION, which is the case the user wants to analyze. The CONSULTANT handles this interaction and, when requested by the user, passes the necessary information to the EXPERT, so that the position can be evaluated and its

similarity metric computed. The evaluation and similarity metric are then passed back to the CONSULTANT, which displays them for the student. Some additional advice may now be requested by the user in order to clarify this information. The CONSULTANT can provide the new advice in the form of a textual description or as visual advice displayed by highlighting relevant squares on the ORIGINAL POSITION. The user can now either modify some of the characteristics of the suggested similarity metric, or use it as is, in order to obtain a list of similar positions from the case base. The similarity metric is passed back to the EXPERT, which uses it to rank the positions in the case base according to their similarity with the case study, and then returns a sorted list that is displayed to the user by the CONSULTANT. The user can then choose from this list those cases to be retrieved for further study. Once retrieved and displayed by the CONSULTANT, cases can be studied by applying to them any of the commands that can be applied to the ORIGINAL POSITION. Furthermore, specific advice about each of the similar cases can be obtained, along with a list of those actions that were recommended for the case retrieved and are likely to be appropriate in the ORIGINAL POSITION.
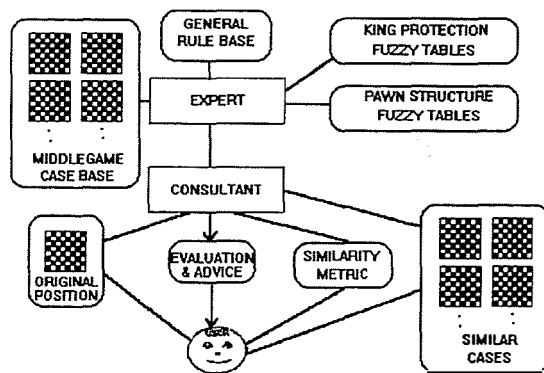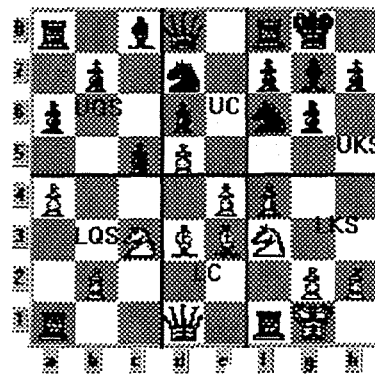

Figure 1: Information Flow in ICONCHESS

Figure 2: Influence Subdivision

3   Chess Knowledge Structures

Since the main focus of ICONCHESS is the middlegame, four main factors are used in the evaluation: material, pawn structure, king protection, and influence. ICONCHESS uses these factors to give detailed information about their relevance, and to compose a similarity metric that can be used to retrieve similar cases from a case base of relevant chess middlegame positions. The material metric indicates not only the material strength for each player, but it can also be used to determine how close the position is to the endgame or opening. The material is computed by using the following standard table of values for each piece and pawn, similar to the one used in [Shannon 50]: king = 200, queen = 9, rook = 5, bishop = 3, knight = 3, pawn = 1. The pawn structure is useful to determine to some extent the type of opening that was used to reach a position, this is the first step to determine the possible strategic objectives for both players. ICONCHESS relies on a set of Fuzzy Tables which are predefined patterns that represent some of the most common pawn structures encountered in the middlegame (i.e. Canonical Structures). Each Fuzzy Table represents one particular Canonical Structure. A Fuzzy Table allows the system to classify the pawn structure that appears in a given position in terms of how close it is to the Canonical Structure represented by this particular Fuzzy Table. In order to determine which Canonical Structure is closer to the pawn structure displayed in a given position, a metric is computed. This metric is called the Closeness Value of the pawn structure of a color corresponding to a given chess position with respect to the Canonical Structure with which it is being compared. Implementation details can be found in [Lazzeri 95]. Three different factors compose a king's protection evaluation in ICONCHESS: the king's location, which allows the program to guess if it has castled or not; the pawn cover, or the number and location of pawns that protect it; the strength of the defensive and attacking pieces that have a direct impact of the king's position. These factors are used to index a table that contains information about specific weaknesses of the specific configuration. The influence metric is an attempt to determine the impact of the fast pieces (e.g. queens, rooks, bishops, and knights) on the different

parts of the board, thereby getting a general idea of the balance of power throughout the board. Influence is related to the well known concept of mobility in chess, and it is defined as the number of possible moves of the fast pieces of a color in 6 different sectors of the board as defined in [Fig. 2], for which the following abbreviations apply: UQS = Upper Queen Side, UC = Upper Center, UKS = Upper King Side, LQS = Lower Queen Side, LC = Lower Center, LKS = Lower King Side.
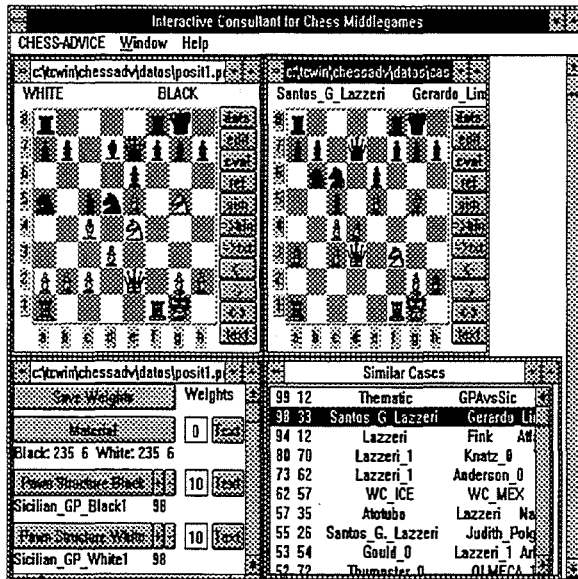

Figure 3: Retrieving a Similar Case
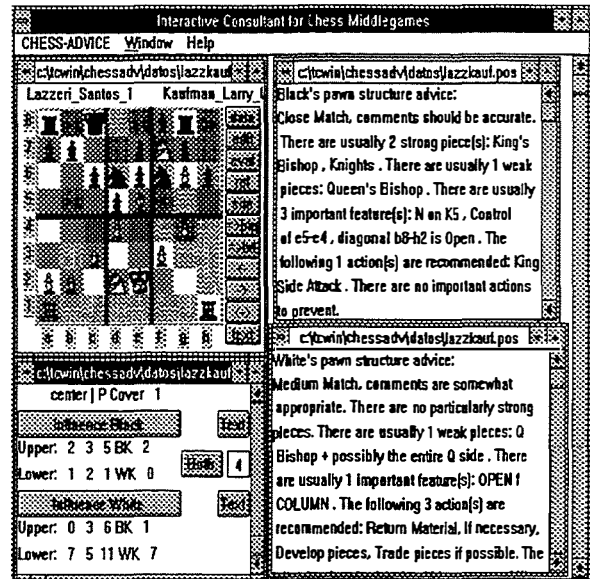
Figure 4: Sample Advice

For any case-based reasoning system to work, it is necessary to develop a similarity metric for the cases or situations that the system will encounter. This similarity metric will allow the program to identify those cases in the knowledge base that are similar enough to the current problem to provide relevant information. In the case of chess positions, it is necessary to consider not only syntactical similarities (i.e. the exact position of pieces), but also semantical similarities (i.e. positions where the strategical goals/plan for each player are similar, even though the actual pieces in the board or their positions are not the same). Previous attempts to formulate a similarity metric for chess positions are described by Levinson [Levinson 85], and Botvinnik [Botvinnik 84]. One of the main contributions of ICONCHESS is the development of a similarity metric that can consider both syntactic and semantic similarities between chess positions. The second main contribution of this work is the development of an algorithm to utilize this similarity metric in order to generate high level advice for a given chess position. ICONCHESS's similarity metric is based on the 4 evaluation factors described above. As the evaluation factors are computed, a specific weight is assigned to each of them according to the particularities of the position. These weights are used to combine the different evaluation factors through a weighted average in order to generate a similarity metric that can be used for retrieval. The weights are an estimate given by the program as to how important each factor is to classify the position. Since it is always desirable to give some degree of control to the user, particularly in learning environments, the user is given the opportunity to select alternative pawn structures and to modify the weights that are involved in the computation of the similarity metric before making the actual search for relevant cases.

ICONCHESS uses 2 different kinds of similarity: 1) Straight Similarity, where white features in the current position are compared to white features in the case and black features in the current position are compared to black features in the case, and 2) Reversed Similarity, white features in the current position are compared to black features in the case and black features in the current position are compared to white features in the case. A list of all the cases in the case base, sorted by straight similarity and displaying also the reversed similarity value for each case, is presented to the user in a Similar Cases Scrolling Window. The user can then select and retrieve the case/cases to look at. The information displayed to identify each case includes Names of Players and Place and Date [Fig. 3]. Each position in the case base contains a case description and provides some high-level advice for both players. The most relevant pieces of information for each case are: 1) Position

Type Descriptors, which give general information about the position, (e.g. open, strategical, etc.), and 2) Recommended Actions for each player, which includes specific actions, as well as the number of moves where each action is illustrated, preconditions per action, goal for each action, success/failure of the action in the case, and a brief textual explanation of the position.

4   Different Types of Advice

For each evaluation factor, a summary advice is presented in a textual/numeric format with a brief evaluation of the position. More detailed advice, visual or textual, can be obtained by clicking on the appropriate buttons. [Fig. 4] illustrates the different types of advice. There are several ways to take advantage of the similar cases in order to get a better understanding of the main issues in the position. The first option is to display the continuations of the similar cases just to get a suggestion about how to proceed from the position we are studying. This approach is particularly useful when the case is highly similar to the position under study. A second analysis is to evaluate the case position and compare the advice provided for each evaluation factor obtained from the two positions being compared. A third way to get advice from the case is to review the summary of the main features of the case and the recommended actions for each player as well as those recommendations that according to ICONCHESS can be transferred from the case to the position under study.

5   Preliminary Tests and Conclusions

Two experiments were done in order to validate the usefulness of ICONCHESS. The format of the main experiment was similar to what is known as a "Simple One-Group Design", with 1 subject pool, and 2 different treatments. In Treatment 1, the subject analyzes a chess middlegame position prior to using ICONCHESS, (i.e. no treatment). After a training session, the subject is asked to use ICONCHESS in order to analyze the position (i.e. Treatment 2), and then modify the original evaluation in case anything new was learned from using ICONCHESS. Finally, the subject is asked to analyze a 2nd middlegame chess position, where the effect of using ICONCHESS on the subject's overall ability to analyze a chess position is observed.

Ten subjects, 7 male and 3 female, ranging in age from mid-20's to mid-50's, in chess skill from beginners that still had trouble understanding special moves, (i.e. castling and promotion), to experts (i.e. approximately 2000 rating points in the U.S. rating system), and in familiarity with the computer platform (MS-Windows) from beginners to advanced users. Most of the users had played against computer chess programs but had not used any computer assisted instructional system for chess at the level of sophistication of ICONCHESS. The users seemed to like the advice provided by ICONCHESS. According to the questionnaires, most of the different categories of advice received an average of at least 3.7 in a scale of 1 - 5 where 1 was the worst possible value and 5 the best possible value. See [Tab. 1], [Tab. 2].

AVERAGE EVALUATION		
Advice	VISUAL	TEXT
Material	3.7	3.3
Pawn Structure	3.9	3.8
King Protection	3.8	4.0
Influence	4.5	4.0

Table 1: Quality of Advice

AVERAGE EVALUATION		
	USEFULNESS	EASE OF USE
Weight Changes	3.0	4.4
Similar Cases	4.1	4.1
Case Advice	4.4	4.0
Transfer Advice	3.9	4.1
Case Browsing	4.6	4.6
Overall	3.8	4.3

Table 2: Usefulness & Ease of Use

It seems that the subjects were able to understand and utilize the advice provided by those categories (e.g. the visual and textual advice for pawn structure) quite well. They were most impressed with the visual advice for influence which was rated at 4.5, close to the maximum possible evaluation. They all found that the way this advice was presented gave them a feel of the distribution of the forces of each player in the chess board at a glance, something that was difficult for them to do without ICONCHESS. The ease of use of the

features related to the case-based advice was rated above 4.0 for all the categories, which indicates that they did not have any major problem understanding or using the interface provided to use those features. Furthermore, the usefulness of most of these features was also ranked high, in the range 3.8-4.6, which indicates that the subjects found the case-based approach to be appropriate to learn new concepts about chess positions. Two features were rated particularly high, case advice at 4.4, and case browsing at 4.6. It seems the subjects found the detailed descriptions of similar cases (e.g. case advice) useful to understand the high level ideas that could be applicable to their problems, while the ability to browse through the moves of similar cases (e.g. case browsing) gave them hints about specific moves or series of moves that could be appropriate to deal with their particular problem positions. These results indicate that the only categories that rounded to 3.0 were the textual advice for material and the usefulness of the ability to change the weights of the components of the similarity metric. The former seemed not to provide much more information beyond what is evident for most players, even the beginners. The latter received the average score primarily because most of the subjects did not have enough a priori knowledge to feel confident in modifying the weights and therefore preferred to follow the program's recommendations. A few of the subjects did not even attempt to use this feature and did not evaluate it at all. The objective of the last section of the questionnaire was to determine, from the point of view of the subjects, if they had found ICONCHESS useful to understand the two positions presented to them. The average values given to the question in this final section were: Knowledge acquired from ICONCHESS about position 1: 3.2, Knowledge acquired from ICONCHESS that was useful to understand position 2: 3.8, Similarity between positions 1 and 2: 1.9. These results show that the advice was to some extent useful for the subjects to understand position 1 (e.g. average evaluation slightly over 3), and more importantly, the subjects found that ICONCHESS provided them with valuable information that helped the subjects in their study of position 2 (e.g. average evaluation close to 4). A few of the users were able to recognize the reversed similarity between both positions, yet only one of them assigned a value as high as 3 to the similarity between the two positions; therefore the average evaluation for that question was so low (i.e. barely below 2). The results obtained from the questionnaires were encouraging, yet their reliability is not very high, since they are only the reflection of the subjective evaluation by the subjects. A more objective evaluation of ICONCHESS was obtained by looking at the performance of the subjects in the tasks presented to them before and after its use.

The Expert Evaluation was done by comparing the performance of the subjects in the questionnaires about position 1 before and after using ICONCHESS, and also in the questionnaire about position 2. We define the concept of profitability to be the degree of a subject's qualitative performance improvement after using ICONCHESS according to the expert observer's judgment. The subjects can be divided into 3 different groups according to the level of profitability (A, B, C). Group A was the group for which the use of ICONCHESS was most profitable. The subjects in this group either made dramatic improvements in their evaluations or were able to refine their ideas after using ICONCHESS. Group B consisted of three subjects who were able to profit to some extent from their session with ICONCHESS, yet not in a way as dramatic as those subjects in Group A. Subjects in this group were able to fine-tune their evaluations and to obtain new evaluation guidelines that were applied in subsequent evaluations. Subjects in Group C did not profit much from ICONCHESS. Some of them obtained a few general ideas. Their level of chess skill was at the extremes of the skill range in the subject pool. This group also consisted of 3 subjects. One of them was an advanced player, while the others were absolute beginners. The results of the main experiment were: 1) The evaluation of ICONCHESS given by the users was positive. The average results indicate that they liked particularly the visual advice on influence and the case advice. 2) The session with ICONCHESS helped most of the users to improve the evaluation of position 1 and to direct their evaluation of position 2. 3) The subjects were able to profit from ICONCHESS at different levels. Subjects who were at the extremes of the subject pool chess skill range (i.e. advanced, beginners) were the ones who profited the least from ICONCHESS, while subjects in the middle of the skill range had an easier time learning from the program. From these observations and results we can conclude that ICONCHESS was useful to provide strategic advice. Even though some of the subjects had problems with some of the features of the program, the average results indicate that the majority of the subjects were able to profit from their session with ICONCHESS. Particularly appealing to the users were the visual advice on influence and the case advice. The advice provided by ICONCHESS reached beyond one specific position, since the subjects were able to apply some of the knowledge obtained while analyzing position 1 in their study of position 2. This is an indication that the case based approach is actually appropriate for teaching chess middlegames. The subjects were able to profit from ICONCHESS at different levels. Some of them greatly improved their understanding of the game, others had smaller gains in knowledge/insight, while others

obtained just a small amount of new knowledge from their experience with ICONCHESS. This is also an indication that the implementation of a student model may improve the ability of ICONCHESS to help more substantially a wider variety of users.

A follow-up experiment was carried out in order to confirm the findings of the first experiment. Two subjects came back for a second session, one from Group A, and one from Group B, according to their results in the first experiment. This experiment only differed from the main one in the level of difficulty of the 2 chess positions used, which was somewhat higher. The elapsed time between the participation of these subjects in the 2 experiments was between 2 and 3 weeks, during which they did not use ICONCHESS. The subject from Group B was a strong chess player who was able to understand quite well the problems in this session, which reduced the impact of ICONCHESS. The other subject, a beginner-intermediate chess player was able to grasp several interesting ideas from using ICONCHESS, including the importance of piece mobility and the concept of reversed similarity. The questionnaires showed similar patterns as those found in the first experiment for these 2 subjects. In short, this experiment confirmed that the level of skill of the subjects was important to determine the usefulness of ICONCHESS. Some of the future work in ICONCHESS that was suggested by the results of the experiments includes the incorporation of larger knowledge bases and the implementation of a student model. Even though ICONCHESS was specifically designed for chess, some of the techniques, such as the schemes used for the similarity metrics may be applied to other domains. The combination of fuzzy logic and CBR as used in ICONCHESS may also be used as the basis for learning systems in other domains that are complex and where exhaustive analysis of possibilities for a given situation are difficult or impossible to achieve. Some domains that meet these conditions are, for example, military applications, medicine, and natural language processing. The definition of problems in those domains is different than those problems presented in chess, but the same principles may be applied. For example, for military strategy, a classification of the different possible deployments of different types of troops and weapons could be developed to be used instead of the knowledge base of pawn structures.

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