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Constraint-Based Explanations in Games

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Abstract

This article describes methods of explanation developed from the properties of constraint-based methods of selection. We define a knowledge-based structure in the field of games. We follow by defining many methods of selection. We show the portability of these methods by giving examples of their applications in the field of games. The methods of explanation linked to these methods of selection are then defined and illustrated by game systems. The interest of the different methods is discussed. We will try to show the pros and cons of the explanations using the methods of selection.

1 INTRODUCTION

This article describes methods of explanation developed from the properties of constraint-based methods of selection. This field of research seems promising and remains a little-studied area [8]. We are going to look at explanations based on methods of selection in the field of games. In the first part this article presents knowledge used in the majority of games. More precisely it defines the notions of *plan*, *goal*, *move*, *strategy* and *tactic*. In the second part the article gives definitions of different methods of selection. Then it gives examples of their applications in the field of games. In a third part we define different methods of explanation associated with methods of selection previously presented. We give examples of explanations produced by game systems using these methods. The interest of the different methods is then discussed. We will try to show the pros and cons of the explanations using the methods of selection.

2 KNOWLEDGE-BASED STRUCTURES IN THE FIELD OF GAMES

When someone participates in a game of reflection he very quickly learns to structure his knowledge in order to obtain the best result. These structures will be described in this section. In fact, most games require the same types of reflection. Thus the notions of plan, goal, move and methods such as strategy and tactic will recur frequently.

2.1 THREE LEVELS OF KNOWLEDGE

The three levels of knowledge in games are moves, goals and plans. A move is an action authorised by the rules of the game in consideration. It means the act of playing a card in Tarot or Bridge or of placing a stone at an intersection in Go. A move allows the player to satisfy generally one or more goals.

A goal is associated with a situation achievable after a sequence of moves which the player tries to predict. In the short term, it is necessary to know that a move permits the player to achieve a goal. The realisation of a goal can be a part of a plan.

A plan is a set of goals, ordered or not. A plan is the long term objective of the program, which permits the player to select the most attractive goals.

In the system GOGOL [1], a possible plan is *to attack a group*. The different goals which permit attacking a group are to: *reduce its territory*, *remove the base*, *remove an eye*, *reduce its influence*, *take the group*.

2.2 THE PASSAGE BETWEEN TWO LEVELS

The strategy is a link between plans and goals. It permits the choice of goals to achieve as a function of a plan which has been fixed. For example each time BATELEUR [6] plays a card, he has to choose from the goals of his plan that which appears to be the best for the situation.

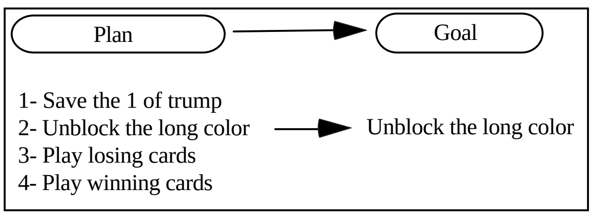


Figure 1: The Passage from a Plan to a Goal

In Figure 1 the system possesses a plan consisting of four goals. The strategy works on the principle that it is better to *unblock the suit* before satisfying the other three goals.

The tactic is a link between goals and moves. It consists of finding one or more moves which best satisfy a fixed goal.

3 METHODS OF SELECTION

To model reasoning, one can use rule-based systems, algorithms which perform tree-searches (of type alpha-beta or A*) or to follow a constraint-based program. The methods of selection which we are studying are based on constraints. These methods have already been used [9,5], but not in the field of systems of explanation. For example, sections 3.2 and 4.3 present systems based on methods of selection by constraints, using bases of rules and search algorithms to give values to the criteria. These evaluated criteria are then used by the method of selection. BATELEUR uses rule bases in order to evaluate cards and GOGOL uses tree search to find the goals which can be reached.

3.1 A DEFINITION OF SELECTION METHOD

In this section, four selection methods will be explained: the conjunctive, disjunctive, lexical and compensatory methods.

Let's consider a set of individuals $\alpha = \{A_1..A_n\}$, a set of criterions $\beta = \{B_1..B_p\}$ and a set of values $\varpi = \{V_{1,1}..V_{n,p}\}$. Each individual A_i is characterised by B_j criterions and a $V_{i,j}$ value is associated to each of the B_j criterions. Then the following formula proves correct:
$\forall A_i \in \alpha, \forall B_j \in \beta, \exists V_{i,j} / (A_i .B_j)=V_{i,j}$.

Now, let's consider a set of constraints $\chi= \{C_1..C_m\}$, a set of standard operators $\theta =\{O_1..O_5\}=\{<, >, =, \geq, \leq\}$ and a set of posts $W=\{W_1..W_z\}$. A constraint is composed with three elements: $C_t = (B_j\ O_g\ W_k)$.

Let f be a function of selection of an individual by a constraint:

$$f: \alpha, \chi \rightarrow \alpha$$
$$(A_i, C_t) \rightarrow A_i \quad \text{If } (V_{i,j}\ O_g\ W_k) \text{ is true}$$
$$\textit{(with } A_i .B_j = V_{i,j} \textit{ and } C_t = (B_j\ O_g\ W_k))$$
$$(A_i, C_t) \rightarrow \{\} \quad \text{if } (V_{i,j}\ O_g\ W_k) \text{ is false}$$

From now in this article, the set parts of any set Z will be written P(Z).

a) The conjunctive method

It is possible to modelize the method as follows:

$$\text{Conjunctive: } P(\chi) \rightarrow P(\alpha)$$
$$(C_1..C_p) \rightarrow \{A_1..A_u\} \text{ with } \forall A_i \in \{A_1..A_u\}, \forall C_t \in P(\chi), f(A_i, C_t) = A_i$$

b) The disjunctive method

$$\text{Disjunctive: } P(\chi) \rightarrow P(\alpha)$$
$$(C_1..C_p) \rightarrow \{A_1..A_u\} \text{ with } \forall A_i \in \{A_1..A_u\}, \exists C_t \in P(\chi), f(A_i, C_t) = A_i$$

c) The compensatory method

This method is particular because of the fact that it does not respect exactly the same principle than the previous methods. As matter of fact, it does not use a set of constraints but it gives coefficients to the selecting criterions. Let's consider a set of coefficient $K = \{K_1..K_p\}$ being associated to the set of criterions $\beta = \{B_1..B_p\}$ so that a K_i coefficient is associated to a criterion B_i. Two compensatory methods are described under-mentioned: the compensatory method with a threshold and the elitist compensatory method.

The compensatory method with a threshold:

Let $S \in \Re$ be a threshold.

$$\text{Compensatorythreshold: } (\beta \text{ x } K)^p \rightarrow P(\alpha)$$
$$(B_1\ K_1) .. (B_p\ K_p) \rightarrow \{A_1..A_u\}$$
$$\text{with } \forall A_i \in \{A_1..A_u\},$$
$$\sum_{j=1}^{p} (V_{i,j} * K_j) \geq S \quad (A_i .B_j = V_{i,j})$$

The elitist compensatory method:

Let $Op \in \{Min, Max\}$ be an operator.

$$\text{CompensatoryOp: } (\beta \text{ x } K)^p \rightarrow P(\alpha)$$
$$(B_1\ K_1) .. (B_p\ K_p) \rightarrow \{A_1..A_u\}$$

with $\forall A_{i1} \in \{A_1..A_u\}, \forall A_{i2} \in \alpha$,
If Op=Max:

$$\sum_{k=1}^{p}(V_{i1,k} * K_k) \geq \sum_{k=1}^{p} (V_{i2,k} * K_k) \quad (A_i .B_j = V_k)$$

d) The lexical method

Let $P(\chi)$, be a well-ordered division of χ with C_{t1} being arranged before C_{t2} and C_{t1} being arranged before $C_{t(j+1)}$.

$$\text{Lexical: } P(\chi) \rightarrow P(\alpha)$$
$$(C_1..C_p) \rightarrow \{A_1..A_u\}$$
$$\text{with } (\text{card}\{A_1..A_u\}>1),\ \forall A_i \in \{A_1..A_u\},\ \forall C_t \in P(\chi), f(A_i, C_t) = A_i$$
$$\text{with } (\text{card}\{A_1..A_u\}=1 \text{ and } \{A_1..A_u\}=\{A_i\}),$$
$$\exists s \in \{1..p\} / (\forall tj \leq s,\ C_{tj} \in P(\chi), f(A_i, C_{tj}) = A_i \text{ and } \forall A_x \in \alpha, A_x \neq A_i, \exists tj \leq s / C_{tj} \in P(\chi), f(A_i, C_{tj}) = \{\})$$

3.2 APPLICATION IN THE FIELD OF GAMES

a) the conjunctive and disjunctive methods

The conjunctive and disjunctive methods will be illustrated thanks to the running of BATELEUR. Let's suppose that the system can play seven cards (α = {R♣, C♣, 9♣, 8♣, R♥, V♥, 5♦}) and that three criterions are associated to these cards (β={*Value of the card, Win the trick*, *The long suit*}). The set of value ϖ may be represented by the Table 1.

Table 1: Evaluation of Cards

	R♣	C♣	9♣	8♣	R♥	V♥	5♦
Value of the card	4.5	2.5	0.5	0.5	4.5	1.5	0.5
Win the trick	3	1	-3	-3	3	0	-3
The long suit	3	3	3	3	-3	-3	-3

The criterion *Value of the card* describes the number of points associated to a card. For example, the V♥ is worth 1.5 points. When a card is evaluated by 3 for the criterion *Win the trick*, it means that the card has a lot of chance to win a trick. An evaluation of -3 shows that the card has few chances to win the trick. Between this two values, others can be inserted. For example, the C♣ has an evaluation of 1 because it has good chances to win the trick, but it is not sure. The third criterion *The long suit* shows the suit with the most important number of cards. A card, which belongs to the long suit, will have an evaluation of 3 (else -3).

When BATELEUR starts a trick that it wants to win with a card of the long suit, it uses the conjunctive method:

Conjunctive	
((The long suit > 0)	(R♣, C♣, 9♣, 8♣)
(Win the trick > 2)	(R♣, R♥)
(Value of the card > 1))	(R♣, C♣, R♥, V♥)
	Selection = (R♣)

When his partner wins the trick and BATELEUR must throw[1] a card, it uses the disjunctive method:

Disjunctive	
((Win the trick < 0)	(9♣, 8♣, 5♦)
(Value of the card > 3))	(R♣, R♥)
	Selection = (9♣, 8♣, 5♦, R♣, R♥)

b) The compensatory method

The following example is taken from the tactic module of the system GOGOL, which learns and make commentaries about the game of Go. For each move GOGOL makes an evaluation of the different parameters associated with the goals fulfilled by the move. In the Table 3, the set of goals which are calculated form a part of the plan *Protect Territory*. We then apply the method:

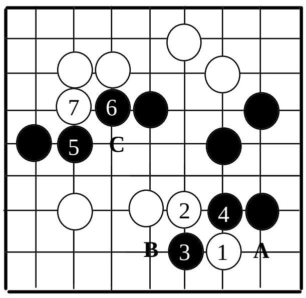


Figure 2: A Configuration of Goban

Compensatory (Stones taken 2) (Stones saved 2)
(Territory saved 2) (Influence saved 1)
(Territory taken 2) (Influence taken 1)

[1] A player throws a card when he has no card in the asked suit and when he has no trump. Then, he must give a card that can not win the trick.

which gives for each move:

Move A: 8 Move B: 13 Move C: 18

The move chosen by the compensatory method from the information given in the Table 3 will therefore be the move C.

Table 3: Evaluation of Moves

Moves	A	B	C
Stones taken	1	1	0
Stones saved	1	1	2
Territory saved	0	0	1
Influence saved	2	2	12
Territory taken	1	2	0
Influence taken	0	3	0

c) The method of lexical selection

The example of the use of the lexical method is based on strategic choice in Chess. Different goals can be interesting in Chess following the chosen strategy. The Table 2 gives values of the degree to which the different goals permit strategic objectives to be reached:

Table 2: Evaluation of Goals

Properties Goals	Attack	Rapid gain	Long term	Importance	Risk
Immobilise the Queen(1)	2	5	2	8	8
Capture the Queen(2)	10	10	5	10	10
Control the center(3)	2	0	1	8	3
Take the King(4)	10	10	10	10	5
Protect the King(5)	0	0	10	10	0
Take a Knight(6)	6	3	3	7	3
Protect a Pawn(7)	0	0	1	1	2

The strategic selection of a plan thus consists of applying the lexical method to strategic constraints:

Lexical	
((Attack > 1)	(1, 2, 3, 4, 6)
(Importance > 7)	(1, 2, 3, 4)
(risk < 5))	(3)
	Selection = (3)

which selects the goal: *Control the center* (3).

4 THE EXPLANATIONS

4.1 GENERAL INTRODUCTION

The first researches in the field of explanations were closely tied to knowledge-based systems, Clancey used the system MYCIN [4] to construct the explicative systems GUIDON [3] then NEOMYCIN [2]. Similarly, Swartout developed the system XPLAIN [10] based on a system of prescription of digitalis: *Therapy Digitalis*

Advisor. These systems are based on the explanation of knowledge and particularly the decomposition of the task into sub-tasks.

But our approach is different and maybe complementary. Our goal is to model the different methods of selection and show the advantages on the level of explanations. Moreover some systems already give explanations based on the methods of selection. The system BATELEUR, which is capable of simulating a Tarot (a card game) player, often uses the lexical method. It allows the system GENECOM [7] to spontaneously engender explanations based on the methods of selection used by BATELEUR.

A method of selection can be used by a rule-based system. For example, BATELEUR has rules of the type "If *goal = throw away bad cards* et *the player must play a heart* then *employ the lexical method* $(C_1..C_p)$". In this case the techniques of explanation proper to the methods of selection can complete the techniques already existing.

The method of selection can equally be employed independently of the system based on rules. In this case, the techniques of explanation proper to the methods of selection must be applied. For example, GOGOL uses the elitist compensatory method and engenders explanations.

Some people have studied the characterisation of facts and rules [11]. It is very useful to know the complexity and importance of a rule or a fact. It is useless to explain a fact which is too complex or too obvious. This technique can complete our approach.

4.2 EXPLANATION FROM SELECTING METHODS

The section gives theoretical methods of explanation for the selecting methods (described in 3.1). A frame of a positive and negative explanation is proposed for each method.

Let $\{C_1..C_p\}$ be the set of constraints associated to a method (conjunctive, disjunctive or lexical). Here, we must keep in mind that $\{C_1..C_p\}$ is ordered for the lexical method.

Let's consider the function of filtering out:
g: $\chi \rightarrow P(\alpha)$
$Ct \rightarrow \{A_1..A_v\}$ so that $\forall A_i \in \{A_1..A_v\}, f(A_i, C_t) = A_i$
Let $\mathbf{A}_O$ be the individual who will be concerned with the explanations (or comments). It is necessary to consider two cases:

+) $A_O \in \{A_1..A_u\}$ you have to give an inquiry based on a positive explanation.

-) $A_O \notin \{A_1..A_u\}$ you have to give an inquiry based on a negative explanation.

a) The conjunctive method

+) $A_O \in \{A_1..A_u\}$ was chosen thanks to the method because $\forall C_t \in \{C_1..C_p\}, A_O \in g(C_t)$

-) $A_O \notin \{A_1..A_u\}$ was not chosen by the method because $\exists C_t \in \{C_1..C_p\} / A_O \notin g(C_t)$

b) The disjunctive method

+) $A_O \in \{A_1..A_u\}$ was chosen by the method because $\exists C_t \in \{C_1..C_p\} / A_O \in g(C_t)$

-) $A_O \notin \{A_1..A_u\}$ was not chosen by the method because $\forall C_t \in \{C_1..C_p\}, A_O \notin g(C_t)$

c) The compensatory method

- <u>The compensatory method with thresholds</u>:

+) $A_O \in \{A_1..A_u\}$ has been chosen by the method because

$$\forall A_i \in \{A_1..A_u\}, \sum_{j=1}^{p} (V_{i,j} * K_j) \geq S$$

This type of formula is not very useful to give explanations. For the compensatory method, it is more judicious to present the criterion which had the most influence on the decision. The positive explanation answers the question "*Why was* A_O *selected ?*". The answer depends primarily on the criterion K_j because this is the element which contributed the most to A_O's weighted marks.

-) $A_O \notin \{A_1..A_u\}$ has not been chosen by the method because

$$\sum_{j=1}^{p} (V_{O,j} * K_j) < S$$

As for the positive explanation, the formula above is not very useful for giving explanations. It is preferable to focus on the criterion of A_O which was the most counter-productive. In order to simplify the research of this criterion, we will suppose that each element is in the same range of values.

Let m be the average value of each criterion, the criterion B_s that the individual A_O has to improve is that in which the biggest difference between the lowest values and the average (the difference is weighted by the coefficient of the criterion): $B_s \in \{B_1..B_p\}$ /
$\forall B_j \in \beta, [(V_{O,j} - m) * K_j] > [(V_{O,s} - m) * K_j]$.

- <u>The elitist compensatory method</u>:

+) $A_O \in \{A_1..A_u\}$ has been chosen by the method because

$$\forall A_i \in \alpha, \sum_{k=1}^{p}(V_{O,k} * K_k) \geq \sum_{k=1}^{p} (V_{i,k} * K_k)$$

The explanation is identical to that produced by the compensatory method with a threshold.

-) $A_O \notin \{A_1..A_u\}$ has not been chosen by the method because:

$$\forall A_i \in \{A_1..A_u\}, \sum_{k=1}^{p}(V_{O,k} * K_k) < \sum_{k=1}^{p} (V_{i,k} * K_k)$$

As for the explanations based on the compensatory method with a threshold, the definition described above is not very explicit. Also it is more judicious to find the criterion which has hurt the individual A_o and helped the individual A_c. To find this criterion B_s, it is first necessary to organise the criteria in descending order following the values $V_{i,j}*K_j$ for the individuals A_c and A_o. Then it is necessary to list the criteria and find the first relevant criterion B_s which verifies the formula $V_{o,s}*K_s < V_{c,s}*K_s$.

d) The lexical method

Given the definition of the lexical method, two possible cases arise: either all the constraints are dealt with or the method has not tested all the constraints because it has found a unique solution during the selection.

- <u>all the constraints are dealt with:</u>

+) *card{$A_1..A_u$}>1*, $A_o \in \{A_1..A_u\}$ has been chosen by the method because $\forall\ C_t \in \{C_1..C_p\}$, $A_o \in g(C_t)$

The positive explanation is identical to that produced by the conjunctive method.

-) $A_o \notin \{A_1..A_u\}$ has not been chosen by the method because $\exists\ C_t \in \{C_1..C_p\}$ / $A_o \notin g(C_t)$

- <u>not all the constraints have been dealt with:</u>

+) *card{$A_1..A_u$}=card{A_o}=1*, A_o has been chosen by the method because $\exists$ s $\in$ {1..p} /

$$\left(\forall\ tj \le s,\ C_{tj} \in P(\chi), f(A_o, C_{tj}) = A_o \text{ and } \forall\ A_x \in \alpha, A_x \ne A_i, \exists\ tj \le s \,/\, C_{tj} \in P(\chi), f(A_x, C_{tj}) = \{\} \right)$$

-) *card{$A_1..A_u$}=card{A_x}=1*, $A_o \ne A_x$, A_o has not been chosen by the method because $\exists$ s $\in$ {1..p} /

$$\left(\forall\ tj \le s,\ C_{tj} \in P(\chi), f(A_x, C_{tj}) = A_x \text{ and } \exists\ tj \le s \,/\, C_{tj} \in P(\chi), f(A_o, C_{tj}) = \{\} \right)$$

4.3 APPLICATIONS IN THE FIELD OF GAMES

The explanations in the field of games are interesting for players who use the systems. They permit them to understand their mistakes and thus to progress faster. They are also interesting for creators of game systems. They permit them to understand the errors of the system and find a way of remedying them.

a) Explanation with the conjunctive and disjunctive methods

We take back the examples of the section 3.2 where BATELEUR uses the conjunctive and disjunctive methods. The two types of explanation (positive and negative) can be used with the application of these two methods in the Tarot game.

Conjunctive	
((The long suit > 0)	(R♣, C♣, 9♣, 8♣)
(Win the trick > 2)	(R♣, R♥)
(Value of the card > 1))	(R♣, C♣, R♥, V♥)
	The choice = (R♣)

+) When the question "*why was the R♣ played?*" is asked, the system answers "*the R♣ was played because it is a card of the long suit, it has a lot of chance to win the trick and it is a card without value (the R♣ is worth 0.5 point).*"

-) When the question "*why was not the 8♣ played?*" is asked, the system answers "*the 8♣ was not played because it has few chances to win the trick and it is a card of small value (the 8♣ is worth 0.5 point).*"

Disjunctive	
((Win the trick < 0)	(9♣, 8♣, 5♦)
(Value of the card > 3))	(R♣, R♥)
	The choice = (9♣, 8♣, 5♦, R♣, R♥)

+) When the question "*why was the R♥ played?*" is asked, the system answers "*the R♥ was played because it is worth a lot of points (the R♥ is worth 4.5 points).*"

-) When the question "*why was not the C♣ played?*" is asked, the system answers "*the C♣ was not played because it can win a trick (Win the trick = 1) and its value is less than 3 points (not like a King or a Queen).*"

b) Explanations with the compensatory method of selection

+) Referring to the compensatory Figure, we get the explanations of the selection of the move:

"*The move C was selected largely because of its 'Influence saved' factor (12).*"

-) If we wish to compare the moves B and C we get:

"*The move B was not selected because the move C is the one which has the largest 'Influence saved' characteristic: the move B has a 'Influence taken' factor of 3, but this is not enough with respect to move C which has an 'Influence saved' factor of 12.*"

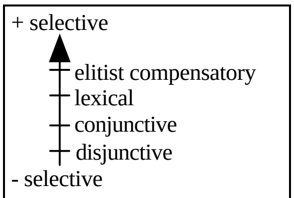
c) Explanations with the lexical method of selection

+) Referring to the Table 2, we get the explanation of the selection of the goal: "*The goal Control the Center has been selected because he has an aggression factor of more than one, an importance superior to 7 and a risk inferior to 5 and is the only instance of this.*"

-) If we wish to compare the goals *Capture the Queen* and *Control the Center* we obtain: "*The goal Capture the Queen was not selected because it has a risk factor of more than 5: its risk is 8. It is not the case for the goal Control the Center: its risk factor is 3.*"

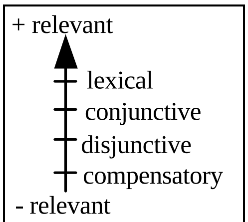
4.4 THE INTEREST OF THE METHODS

Each method presented in this article has its own characteristics. This section consists of regrouping the methods following different properties notably to evaluate their effectiveness for explanations.



The methods

A characteristic of the methods is the capacity to be the most selective possible. In fact this is the aptitude of having the most restricted selection possible. The elitist compensatory method is the most selective, because it only selects one individual. The lexical method is also selective because it privilegiates the selection of a single individual. On the other hand, the disjunctive method is by far the least restrictive because it is only necessary to fulfil one condition in order to be chosen. The case of the compensatory method with a threshold is a particular case, because it can be very restrictive or very unrestrictive, according to the level of the threshold.



The explanations

The difficulties of the compensatory method are due to its dependence on the domain of application. According to the field of application the values of the different criteria can lie in entirely different ranges. Thus, a criterion which lies in the range [0...5] will not have the same importance at all as one lying in the interval [10...100]. It is difficult to find the criteria which have contributed to making a choice. This is a drawback to explanation. The other methods which have constraints which are much more explicit do not have this problem.

The lexical method treats its constraints one after the other following an order of priority. This sequential treatment is not used by the conjunctive and disjunctive methods, which examine their constraints with no fixed order. This difference explains why explanations based on the lexical method are often more precise. The identification of the constraints to explain is easier. In addition, the explanations use the order of priority to evaluate the importance of the constraints. The disjunctive method is less relevant for explanations than the lexical and conjunctive methods because it is a lot less restrictive.

5 CONCLUSION

We have defined the notions commons to many games: plans, goals, moves, strategy and tactics. The article showed different methods of selection based on constraints. The methods of selection are easy to implement and use. They are general and are not dependent of the system explained. This is an advantage with respect to classical explanation systems which use reasoning based on rules: there is no need to create ideal student model and consequently, no need for large scale empirical studies of domains experts and there is no need to create bug library and, consequently, no need for large scale empirical studies of students to create and validate such bug libraries [8]. Each of the method of selection employed was associated with a method of explanation. The explanations could be the reasons for selection or the reasons for non-selection. To better illustrate our propositions, numerous examples of the methods of selection and explanation were presented. They were mainly illustrated by the use of two operational systems: BATELEUR for the game of Tarot and GOGOL for the game of Go. We compared the interest and usefulness of the methods presented for selection and explanation. It is revealed that explanations based on constraints are better adapted to the conjunctive and lexicographic methods than to the disjunctive and compensatory methods.

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