

THE USE OF INFORMAL CALCULUS IN PROBLEMS OF ARTIFICIAL INTELLECT

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For taking decisions in complicated situations, especially with the help of computers, various heuristic methods are often used. However, their use is individual in character and requires special apparatuses for every new problem.

The present report outlines principles of a possible general apparatus of informal calculus and observes its application to the problem of taking intellectual decisions.

By human intellect we mean a complex of mental abilities that ensures man's behaviour in complicated situations. Accordingly, by one of the principal intellectual functions of some artificial apparatus, first and foremost a computer, we may mean its ability to come to independent reasonable decisions. To reflect these sensible decisions or operations in intellectual problems the present paper dwells upon the use of operations of the informal calculus apparatus suggested by the author (1).

The realization of these problems will be carried out by an abstract computer, referred here to as a system computer. It can also be a man with the necessary training, or, for some types of problems, a computer supplemented with the model operations of informal calculus.

The essential credit of these opera-

tions is their non-determination, i.e. ambiguity and informality of their results. Consequently, the realization of various intellectual problems may proceed in different ways. Thus we have a calculus on hand (2, p.203), i.e. we have permission to carry out some operations.

For example, if we add 1 and 8 with the aim of getting an arithmetic sum, we shall get number 9. However, if we add 1 and 8 with the intention of getting a new two-figure number, we shall get 18. Further, if we add 1 and 8 with the aim of getting a new symmetrical figure, we shall get 8 , but if we simply aim at any new figure, we shall get figures 18 or 8 or 81 , i.e. three different possible results. Obviously, it is the realization of some general summation operation that below will be referred to as the system summation operation.

It should also be noted that for the man informal calculus operations are strictly enough determinable by intuition as they, first and foremost, formalize common arithmetic operations with objects and notions. However, the use of such operations in intellectual problems does not serve the purpose of copying the structure of man's thinking.

For realizing of informal calculus operations it is necessary to give rules governing the representation of real system on the level of a computer which

is able to realize these operations.

In this case, some real system [A] is represented by some set /A/, called here the system representing structure, of the symbols of the chosen alphabet

$$/ \alpha'_1, \alpha'_1, \alpha'_2, \alpha'_2, \dots / \quad (1)$$

for describing

$$\left. \begin{array}{l} \text{the elements } [\alpha_1, \alpha_2, \dots] \\ \text{and the links } [\alpha_1, \alpha_2, \dots] \end{array} \right\} \quad (2)$$

in the system [A], the context (1) of which is meaningful for its goal K. In other words, (1) and (2) together provide for an unambiguous representation of the system A in the structural form of /A/, retaining the goal K. The goal K makes it possible to eliminate from the observation a great number of elements and practically all the links of the real system, and it also dictates a strict succession in (1).

Let us call such a complex of elements and links of the system [A], arranged into a succession according to the goal K a sequence of numerals of the system [A] with respect to the goal K, and the very successive elements and links of this system in consideration of their interaction - numerals of the system [A] with respect to the goal K.

It is possible to eliminate the unnecessary elements and links from the real system and to arrange the remaining ones into a sequence only in case we have sufficient general knowledge in the field of science to which the given system and its respective goal K belong.

For the initial operation of informal calculus the taking of a decision when two objects or notions [A] and [B] coincide according to the goal K has been chosen. Here, this operation is designated as the system coincidence operation and is marked by the following

symbol,

$$\dots (=K) \dots \Rightarrow \text{YES or NO.}$$

Due to its contents this operation is on the level of elementary human intellectual decisions. The process of learning occupies an important place in the realization of this problem.

For the realization of the system coincidence operation one should establish for the representing structures /A/ and /B/ of real systems or their corresponding pair-elements

$$/a_1, a_2, \dots, a_n/ = /A/$$

$$/b_1, b_2, \dots, b_n/ = /B/$$

a sign of physical, technological or meaningful coincidence with respect to the given goal K,

$$/A/(=K) /B/ \Rightarrow \text{YES or NO,}$$

or

$$(a_1, \dots, a_n) (=K) /b_1, \dots, b_n/ \Rightarrow \text{YES or NO.}$$

In the latter case, the presence of coincidence or lack of coincidence is given separately for the possible pairs $a_1:b_1$ of the structures /A/ and /B/.

Here are some examples of system coincidence:

1. /<DESK-LAMP> / (= <FORMATION OF LAMP-FITTINGS>) /<STANDARD LAMP> / $\Rightarrow$ YES.

2. In a shop of discrete production it is necessary to control the normal state of production with respect to the realization of the plan by the end of the month. The state of production is characterised by the system [A] representing a number of actually completed single operations a_j

$$/a_1, a_2, \dots, a_j, \dots, a_n/ = /A/.$$

At the same time, we have a lay-out plan [B] which requests an amount b_j of these completed operations j by the given date:

$$/b_1, b_2, \dots, b_j, \dots, b_n/ = /B/.$$

It is generally known that a foreman, despite the condition $a_j \neq b_j$ in separate element-pairs, can, nevertheless, determine that "the state of production is normal", i.e.

/A/ (= <NORMAL STATE OF PRODUCTION>) /B/ $\Rightarrow$ YES

by subconsciously taking into consideration a wide range of factors.

The indicated problems may be related to the intellectual ones as the direct apparent information in this case is incomplete. If the problems are realized in a system computer, the participating objects or notions, which will be chosen by the goal K and transferred by it into sequences, are called in the apparatus described here - the sequences of numerals.

As an example, let us follow the formation of the sequence of numerals of the system [C] with the respective goal K_1 :

K_1 - "formation of pieces of furniture for sitting".

It is known that there are exceptionally many types of such pieces (i.e. systems), like chairs, armchairs, seats of various styles.

The formation of the sequence of numerals should follow the complex of knowledge pertaining to [C] and K_1 . However, in the present report examples have been simplified and this complex of knowledge has been replaced by the following two rules which take into account only functional properties of the system [C] elements, though their technological, ornamental and other possible properties should also be considered.

1. An element of the system with the highest functional meaning should stand in the sequence of numerals before an element with a lower functional meaning.

2. The sequence of numerals must be

preserved in correspondence with the given goal K if elements of lower functional meaning are excluded.

In this case, the sequence of numerals for the system [C] with respect to the goal K_1 acquires the following structure,

/C/ = /<SEAT>, <LEGS>, <BACK>.../(3)
The circumstance, that the following structures

/H/ = /<LEGS>, <SEAT>, <BACK>.../ (4)

/M/ = /<BACK>, <LEGS>, <SEAT>.../ (5)

are incorrect sequences of numerals of the system [C] and do not satisfy the goal K_1 , can easily be proved if we apply to them the above-stated rules.

On the other hand, we can see that when we check the conformity of the highest functional elements of (4) and (5) following the goal K_1 with those of (3) as a whole, we accomplish the system coincidence operation,

/C/ (= K_1) /<LEGS> / $\Rightarrow$ NO

/C/ (= K_1) /<BACK> / $\Rightarrow$ NO

where

NO - stands for the lack of system coincidence.

The following operation, that in system sense is opposite to that of system coincidence operation, should be of great importance in intellectual problems. It is "the operation of searching for a coincidental system",

/A/ (YES = K) $\Rightarrow$ /B/

where

[A] is the initial system,

K the goal in the search for a coincidental system for [A],

/B/ the result of the operation, i.e. [B] is the system that has system coincidence with /A/ with respect to the goal K.

This operation will be realized by searching for the coincidental system from the whole capacity of the memory of

the system computer which can be: an abstract system computer, man with adequate training, and for some sets of problems, a usual computer with a model that, in addition, includes the model of the system coincidence operation.

The system summation operation
 $/A/ (+K) /B/ \Rightarrow /B/, /A_{REST}, B_{REST}/,$

represents the joining of two systems [A] and [B], and their resultant system [D] will have new qualities determined by the goal K. Here $/A_{REST}, B_{REST}/$ are the unused elements of the systems [A] and [B].

The application of the described operation allows to lay down the realization of a highly intellectual problem, as for example, the formation of a new system of generalized complex notions from two systems of elementary notions. In the development of science we find well-known examples of this operation, like the formation of mathematical economy from the concepts of mathematics and economy, or physical geography from physics and geography.

This requires the joining of the structures representing initial systems [A] and [B] of elementary notions a_i and b_j :

$$/A/ = /a_1, \dots, a_i, \dots, a_n/$$

$$/B/ = /b_1, \dots, b_j, \dots, b_m/$$

into a new system [D] of complex notions d_o , the representing structure of which will be

$$/D/ = /d_1, \dots, d_e, \dots, d_k/.$$

If the problem is presented in a generalized form, the contents of the goal of the system summation operation will be the following,

K - "formation of complex notions".

Let us consider the required algorithm of the system summation operation

in an example.

1. Using the system coincidence operation with respect to the goal K we check the general principal potentiality of each element a_i of the system [A] to form complex notions with the elements of the system [B]:

$$a_i (=K) b_1 \Rightarrow \text{YES or NO}$$

.....

$$a_i (=K) b_m \Rightarrow \text{YES or NO}.$$

As a result we get initial or original variants of complex notions, for example,

$$/a_i:b_d, \dots, a_i:b_m, \dots, a_i:b_e, \dots,$$

$$a_i:b_j, \dots/ = /A_i:B_j/.$$

2. In order to draw from these initial complex notions a final comprehensive system of complex notions, we must introduce a basic system [E],

$$[E] = [e_1, \dots, e_k].$$

As a rule, [E] represents a system of generalized notions for the presupposed elements of the system [D]. The system [E] may also be taken from the branch of science analogical to that of the system [B].

In this way, the application of [E] must guarantee the meaningfulness of the next step of the decision.

3. Elements of the final system-variant

$$[D] = [d_1, \dots, d_k],$$

come forth with the use of the operation of searching for a coincidental system for each element of the system E separately. The search here includes the structure of initial variants of complex notions $/A_i:B_j/$:

$$e_1 (\text{YES} = K_1) /A_i:B_j/ \Rightarrow d_1$$

.....

$$e_k (\text{YES} = K_1) /A_i:B_j/ \Rightarrow d_k,$$

In this case, the goal K_1 stands for,

K_1 - "to secure the greatest meaningfulness".

The operation of searching for a coincidental system as stated before, is realized by the use of system coinci-

dence operation in the structure of common algorithms. Consequently, the system summation operation, according to the described algorithm, can be realized on condition of the realization of the system coincidence operation.

For many problems of taking intellectual decisions a model of operation of system coincidence can be implemented for a usual computer.

One of these models has been successfully tested by the author for the realization of the problem "determina-

tion of the normal state of production", which has been described in the beginning of the report.

Reference

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