THE USE OF INFORMAL CALCULUS IN PROBLEMS OP ARTIFICIAL INTELLECT

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

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

By human intellect we mean a complex of mental abilities that ensures man's behaviour in complioated 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 caloulus 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 neoessary training, or, for some types of problems, a computer supplemented with the model operations of informal oaloulus.

The essential credit of these operations 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 caloulus 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 @ , but if we simply aim at any new figure, we shall get figures i8 or 4 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 oommon 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 caloulus operations it is neoessary to give rules governing the representation of real system on the level of a computer whioh is able to realize these operations.

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

$$/\, a'_1,\ \alpha'_1,\ a'_2,\ \alpha'_2,\ \ldots /$$

for describing

$$\left.\begin{array}{l}\text{the elements } \{a_1, a_2, \ldots\} \\ \text{and the links } \{\alpha_1, \alpha_2, \ldots\}\end{array}\right\} \quad (2)$$

in the system [A] , the context (1) of which is meaningful for its goal K. In other words, (1) and (2) together pro-Tide for an unambiguous representation of the system A in the structural form of /A/, retaining the goal E. 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 suocesion in (1).

Let us call such a oomplex of elements and links of the system [A] , arranged into a succession aooording to the goal *K* a sequence of numerals *of* the system [A] with respect to the goal Z, 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 one8 into a sequence only in case we have sufficient general knowledge in the field of soience 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,

...(=K)... ⟹ 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

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

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

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

/A/(=K) /B/ ⟹ YES or NO,

or

$(a_1, \ldots, a_n)$ (=K) $/b_1, \ldots, b_n/$ ⟹
⟹ YES or NO.

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

Here are some examples of system coincidence:

1. / <DESK-LAMP> / (= <FORMATION OF LAMP-FITTINGS>)/<STANDARD LAMP>/⟹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

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

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:

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

It is generally known that a foreman, despite the condition $a_j \not\succ b_j$ in separate element-pairs, can, nevertheless, determine that "the state of production is normal", i.e.

/A/ (= <NORMAL STATE OF PRODUCTION>) /B/ ⟶ YES

by subonsciously taking into consideration a wide range of factors.

The indloated problems may be related to the intellectual ones as the direct apparent Information in this oase Is Incomplete. If the problems are realised in a system oomputer, the participating objects or notions, which will be ohosen 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 - "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 replaoed by the following two rules which take into acoount 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 exoluded.

In this oase, the sequence of numerals for the system [C] with respect to the goa K_1 :quires the following structure,

/C/ = / <SEAT> , <LEGS> , <BACK> .../(3)

The circumstanoe, 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, 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 with those of (3) as a whole, we accomplish the system coincidence operation,

/C/ (=K_1) / <LEGS> / ⟶ NO

/C/ (=K_1) / <BACK> / ⟶ 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) ⟹ /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 abstraot 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 ooincidence operation.

The system summation operation

$$/A/ \ (+K) \ /B/ \Longrightarrow /B/, \ /A_{REST}, B_{REST}/,$$

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

The applioat ion of the described operation allows to lay down the realisation of a highly intellectual problem, as for example, the formation of a new system of generalized oomplex 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 eco - nomy from the concepts of mathematics and economy, or physical geography from physios and geography.

This requires the joining of the structures representing initial systems [A] and [B] of elementary notions a, and b.:

$$/A/ = /a_1, \ldots, a_1, \ldots, a_n/$$
$$/B/ = /b_1, \ldots, b_j, \ldots, b_m/$$

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

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

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

K - "formation of complex notions"*

Let us oonsIder the required algorithm of the system summation operation in an example.

1. Using the system ooinoidenoe operation with respeot to the goal K we oheok the general principal potentiality of each element a, of the system (A) to form oomplex notions with the elements of the system fB 1 :

$$a_1 \ (=K) \ b_1 \Longrightarrow \text{YES or NO}$$
$$\ldots\ldots\ldots$$
$$a_1 \ (=K) \ b_m \Longrightarrow \text{YES or NO.}$$

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

$$/a_1{:}b_d, \ldots, a_1{:}b_m, \ldots, a_1{:}b_e, \ldots, a_1{:}b_j, \ldots/ = /A_1{:}B_j/.$$

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

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

As a rule, [B] represents a system of generalised 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

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

come forth with the use of the operation of searching for a coincidental system *tor* eaoh element of the system E separately. The search here inoludes the structure of initial variants of complex notions $/A_1{:}B_1/$:

$$e_1 \ (\text{YES} = K_1) \ /A_1{:}B_j/ \Longrightarrow d_1$$
$$\ldots\ldots\ldots\ldots$$
$$e_k \ (\text{YES} = K_1) \ /A_1{:}B_j/ \Longrightarrow d_k,$$

In this oase, the goal K_1 stands for,

K^ - "to secure the greatest meaningfulness** •

The operation of searching for a coincidental system as stated before, is realised by the use of system ooinoideno e operation in the struo tur e of common algorithms. Consequently, the system summation operation, according to the described algorithm, oan be realized on oonditlon of the realization of the system oolncldenoe operation.

For many problems of taking Intel* lectual 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 "determination of the normal state of production", which has been described in the beginning of the report.

Referenoe

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