STUDY ON KNOWLEDGE REASONING BASED ON EXTENDED FORMULAS

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Abstract: In artificial intelligence, knowledge representation and knowledge reasoning are very important problems. There are different reasoning rules for different knowledge representation methods. In this paper, extended formulas are established based on the extended analysis principle of basic-element , and the new knowledge representation methods and knowledge reasoning modes with extended formulas are put forward. Accordingly extended reasoning modes are established. The study will provide new formalized tools for knowledge mining and new reasoning technique for solving contradiction problems.

Key words: extended formula, knowledge reasoning, basic-element, knowledge representation, problem solving

1. INTRODUCTION

Extenics studies the extensibility of things, the rules and methods for opening up things, and then uses them to solve contradiction problems with formalized models.[1] Its study objects are contradiction problems in the real world and its logic cells are basic-elements, including matter-element, affair-element and relation-element. Its logic base is extension logic.[2] Its fundamental theory is extension theory, containing three pillars— basic-element theory, extension set theory and extension logic.

Extenics has a special method of its own called extension method, containing extension analysis method, extension transformation method, conjugate analysis method and extension set method. The technology applying extension theory and extension method to different special fields is called extension engineering[3]. *Extenics* has been in great progress, which has been made in both basic theory and application research. Not long after the birth of extension theory, many experts point out that "extension theory has very strong relation with AI"[4] and "it must penetrate into AI and its related subjects". [5] AI and *Extenics* are interrelated, which can be seen from their development process.

In AI, knowledge representation and knowledge reasoning are very important problems. There are different reasoning rules for different knowledge representation methods[6]. In this paper, extended formulas are established based on the extended analysis principle of basic-element, and the new knowledge representation methods and knowledge reasoning modes with extended formulas are put forward. Accordingly extended reasoning modes are established. The study will provide new formalized tools for knowledge mining and new reasoning technique for solving contradiction problems.

2. BASIC-ELEMENTS AND KNOWLEDGE REPRESENTATION

Basic-elements, including matter-element, affair-element and relation-element, are logic cells of *Extenics*. They can be used to express varied knowledge and get the form of knowledge representation standardization.

2.1 The concepts of basic-elements

The world is formed by all things. The reciprocity among things is called affairs. Things, affairs and their relations make up of the real world. In order to describe things, affairs and their relations with formalized methods, The conceptions of matter-element, affair-element and relation-element are provided.

Matter-element is a basic element to describe a matter. The ordered three-dimensional group $R = (N, c, v)$ is called a matter-element. A matter' s name N, its characteristic c and the measure v about c are three key elements of a matter- element.

A matter can have more than one characteristic. If we express a matter N with its n characteristics $c_1, c_2, \cdots, c_n$ and the corresponding measures $v_1, v_2, \cdots, v_n$; the matter-element can be denoted by

$$R = \begin{bmatrix} N, c_1, v_1 \\ c_2, v_2 \\ \cdots\cdots \\ c_n, v_n \end{bmatrix} = \begin{bmatrix} R_1 \\ R_2 \\ \cdots \\ R_n \end{bmatrix}$$

R is called a n-dimensional matter-element, where $R_i = (N, c_i, v_i)$ is called R's component matter-element.

Affair-element is a basic element to describe an affair. The ordered three-dimensional group $I = (d, b, u)$ is called an affair-element. A verb' s name d, its characteristic b and the measure u about b are three key elements of an affair-element.

Be similar to a n-dimensional matter-element, a n-dimensional affair-element can be denoted by

$$I = \begin{bmatrix} d, b_1, u_1 \\ b_2, u_2 \\ \cdots\cdots \\ b_n, u_n \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ \cdots \\ I_n \end{bmatrix}$$

Relation-element is a basic element to describe a relation. The ordered three-dimensional group $Q = (s, a, w)$ is called a relation-element. A relation's name(or relation's symbol) s, its characteristic a and the measure w about a are three key elements of a relation-element.

2.2 The knowledge representation methods based on basic-element

The traditional artificial intelligence(AI), based on symbol and logic, solves problems by knowledge representation and knowledge reasoning[6]. There are many different representation methods for the same problem, and they have different representation space. Whether the representations of a problem are good or not has great influence to the results and workload of solving the problem. Therefore, it will greatly improve the efficiency of problem solving in AI that properly selecting and correctly using knowledge representation methods.

There are many kinds of knowledge representation methods, such as predicate logic method, semantic network, frame representation, production rule and process representation, etc.. All of them have their own advantages and disadvantages[6]. Basic-elements, their operation formulas and compound-elements can give the representation methods a united form. That is to say, we can use basic-elements to represent predicate, production rule, semantic network and frame, etc[2]. Representing knowledge with basic-elements, we can use transformation and reasoning to generate new knowledge and form new knowledge reasoning methods. It will raise the feasibility of problems solving, especially contradiction problems.

3. EXTENDED FORMULAS OF BASIC-ELEMENT

Basic-elements have extensibility. According to their extensibility, the document [2] studies the extended analysis principles, including divergent analysis principle, correlative analysis principle, implication analysis principle and opening-up analysis principle. Take matter-element as example, according to these principles, we can get the following extended formulas, which are the "knowledge" in AI.

(1) divergent formulas of matter-element

Given a matter-element $R=(N, c, v)$, then

$R\dashv \{R_i \mid R_i=(N,\ c_i,\ v_i),\ i=1, 2, \cdots, n\}$

or $R\dashv \{R_i \mid R_i=(N_i,\ c,\ v_i),\ i=1, 2, \cdots, n\}$

or $R\dashv \{R_i \mid R_i=(N_i,\ c_i,\ v),\ i=1, 2, \cdots, n\}$

or $R\dashv \{R_i \mid R_i=(N,\ c,\ v_i),\ i=1, 2, \cdots, n\}$

or $R\dashv \{R_i \mid R_i=(N,\ c_i,\ v),\ i=1, 2, \cdots, n\}$

or $R\dashv \{R_i \mid R_i=(N_i,\ c,\ v),\ i=1, 2, \cdots, n\}$

They can be denoted by $R\dashv\ R_i=(N_i,\ c_i,\ v_i)$ for short, and be called divergent formulas. When $N=N_i$, we call R and R_i matter-elements with the same matter. When $c=c_i$, R and R_i are called matter-elements with the same characteristic. And when $v=v_i$, R and R_i are called matter-elements with the same maesure. The same below.

(2) correlative formulas of matter-element

Given a matter-element $R=(N, c, v)$, if there exist matter-elements $R_i=(N_i,\ c_i,\ v_i)$, (i=1,2,…,n), and $v_i=f(v_1)$, then $R\sim R_i$(i=1,2,…,n), which are called correlative formulas.

(3) implication formulas of matter-element

Given a matter-element $R=(N, c, v)$, to certain matter-elements $R_i=(N_i,\ c_i,\ v_i)$, (i=1,2,…,n), if R@, there must be R_i@, then $R \Rightarrow R_i$(i=1,2,…,n), which are called implication formulas.

(4) opening-up formulas of matter-element

Given a matter-element $R=(N, c, v)$, if there exist matter-elements $R_i=(N_i,\ c_i,\ v_i)$, (i=1,2,…,n), so that

$$\begin{bmatrix} N \oplus N_i, & c, & v \oplus c(N_i) \\ & c_i, & v_i \oplus c_i(N) \end{bmatrix} \quad @$$

then ($R \oplus R_i$)@, denoted by

$$R \oplus R_i = \begin{bmatrix} N \oplus N_i, & c, & v \oplus c(N_i) \\ & c_i, & v_i \oplus c_i(N) \end{bmatrix}$$

And we call them combined formulas.

Given a matter-element $R=(N, c, v)$, if there exist matter-elements $R_i=(N_i,\ c_i,\ v_i)$, (i=1,2,...,n), so that $R = R_1 \oplus R_2 \oplus \cdots \oplus R_n$, then

$$R/\{R_1, R_2, \cdots, R_n\}.$$

And we call it decomposition formula.

4. EXTENDED REASONING MODES-----THE KNOWLEDGE REASONING MODES BASED ON EXTENDED FORMULAS

According to the above-mentioned extended formulas, we can get the following knowledge reasoning modes:

(1) divergent reasoning modes

$$(N,\ c,\ v)\wedge[(N,\ c,\ v)\dashv(N_i,\ c_i,\ v_i)]\models(N_i,\ c_i,\ v_i)$$

The formula means that $(N,\ c,\ v)\dashv(N_i,\ c_i,\ v_i)$ are divergent formulas. If $(N,\ c,\ v)$ is a fact, then $(N_i,\ c_i,\ v_i)$ are facts. In the formula, $(N_i,\ c_i,\ v_i)$ can be the matter-elements with the same matter, the matter-elements with the same characteristic, or the matter-elements with the same measure, etc..

(2) correlative reasoning modes

$$(N,\ c,\ v)\wedge[(N,\ c,\ v)\sim(N_i,\ c_i,\ v_i), v_i=f(v)]$$
$$\models[(N_i,\ c_i,\ v_i), v_i=f(v)]$$

(3) implication reasoning modes

$$(N,\ c,\ v)\wedge[(N,\ c,\ v)\Rightarrow(N_i,\ c_i,\ v_i)]\models(N_i,\ c_i,\ v_i)$$

(4) opening-up reasoning modes

$$(N,\ c,\ v)\wedge(N_i,\ c_i,\ v_i)\wedge$$
$$\left\{(N,\ c,\ v)\oplus(N_i,\ c_i,\ v_i)=\begin{bmatrix} N\oplus N_i, & c, & v\oplus c(N_i) \\ & c_i, & v_i\oplus c_i(N)\end{bmatrix}\right\}$$
$$\models\begin{bmatrix} N\oplus N_i, & c, & v\oplus c(N_i) \\ & c_i, & v_i\oplus c_i(N)\end{bmatrix}$$

$$(N,\ c,\ v)\wedge[(N,\ c,\ v)/\{(N_1,\ c_1,\ v_1),\cdots,(N_n,\ c_n,\ v_n)\}]$$
$$\models\{(N_1,\ c_1,\ v_1),(N_2,\ c_2,\ v_2),\cdots,(N_n,\ c_n,\ v_n)\}$$

Taking advantage of the above knowledge reasoning modes, we can provide many kinds of formalized, operative thoughts and approaches for problems solving. It is especially more effective to contradiction problems solving.

5. CASE STUDY------SOLVING CONTRADICTION PROBLEMS WITH EXTENDED REASONING

[A monkey picks bananas] A room has the height of 2.8m. At 1.8m above the ground, a handful of bananas *B* hang. The monkey *A* wants to pick *B*. But when standing up, its body height is 0.5m, and its touching height is 0.7m. There are an estrade, which is 1.4m high and has a weight of 15kg, a chair, 0.5m high and a weight of 5kg, a cabinet, 1.8m high and a weight of 50kg, and a table, 1.2m high and a weight of 20kg. Suppose these objects are mobile(can be moved or be pushed), and the biggest impetus of *A* is 25kg(that it is, *A* can push the objects under 25kg weights).

Now we use the knowledge representation methods based on basic-element and extended reasoning to solve the contradiction problem. Therefore, we should formulate the problem and its core problem with formalized method.Suppose the goal is

$$G=\begin{bmatrix} obtain, & subjection\ \ object, & bananas\ B \\ & executive\ \ object, & monkey\ \ A \\ & position, & 1.8m\ \ height \end{bmatrix}=\begin{bmatrix} d, & b_1, & B \\ & b_2, & A \\ & b_3, & 1.8m \end{bmatrix}$$

the condition is

$$L=(A,\ \text{height},\ 0.5\text{m})=(A,\ c_0,\ 0.5\text{m})$$

the problem is denoted by $P=G*L$.

Assume the appraisal characteristic c_0=height. c_{0s}, whose domain of value-measures is X_0=<1.8, 2.8>, is the needed height for realizing the goal G. c_{0t} is the height which is provided by z_0 in condition L. In this case, $z_0 = L$ =(A, c_0, 0.5m), then $c_{0t}(z_0)$=0.7m(touching height).

Let $W = \{g|g = (z,\ c_{0t},\ c_{0t}(z)) = (z,\ c_{0t},\ x), z \in \{z_{0\dashv}, z_{0\sim}, z_{0\oplus}, z_{0\Rightarrow}\}\}$, then the core problem of the original problem P is

$$P_0 = g_0 * l_0 = (z_0,\ c_{0t},\ c_{0t}(z_0)) * (z,\ c_{0s},\ X_0).$$

According to the actual problem, we can establish the dependent function

$$k(x)=\frac{x\text{ - }\mathbf{1.8}}{\mathbf{2.8}\text{ - }\mathbf{1.8}}=x-\mathbf{1.8}$$

To $\forall g = (Z,\ c_{0t},\ x) \in W, Z = (N, c, c(N)), c = c_0$ or c and c_0 is the characteristics with the same domain of measures, let

$$\widetilde{A}(T) = \{(g,y,y') | g \in T_W W, y = K(g) = k(x), y' = T_K K(T_g g)\}$$

then

$$K_0(P) = K(g_0) = k[c_{0t}(Z_0)] = \frac{\mathbf{0.7 - 1.8}}{\mathbf{2.8 - 1.8}} = \mathbf{-1.1 < 0}$$

So the problem P is an incompatible problem. The reason is the value of c_{0t} (touching height) cannot fulfill the request of the problem.

Now we take advantage of the extended reasoning modes to solve this incompatible problem. To be simple, we only show the application of divergent reasoning mode and expansile reasoning mode.

(1) Making use of divergent reasoning modes

$$(Z_0) \wedge (Z_0 \dashv (A_i,\ c_0,\ c_0(A_i)) = Z_i) \models Z_i,\ (i=1,2,\cdots,n)$$

Let

$$g_i = (Z_i,\ c_{0t},\ c_{0t}(Z_i)) \triangleq (Z_i,\ c_{0t},\ x_i)$$

According to the definition of dependent function, to make $y = K(g_i) > 0$, we need $k(x_i) > 0$, that is $k(c_{0t}(Z_i)) = c_{0t}(Z_i) - 1.8 > 0$. Therefore, we can get $c_{0t}(Z_i) > 1.8$.

Then make a transformation ,

$$T_1 = \begin{bmatrix} replace\ , & b_1, & A \\ & b_2, & A_i \end{bmatrix}$$

That is, we can use a life-form A_i, whose touching height is over 1.8m to replace A. So

$$T_1 g_0 = (T_{1Z_0} Z_0, c_{0t}, c_{0t}(T_{1Z_0} Z_0)) = ((A_i, c_0, c_0(A_i)), c_{0t}, c_{0t}(z_i))$$
$$K(T_1 g_0) = k(c_{0t}(Z_i)) > 0$$

Now the incompatible problem is transformed to a compatible one.

(2) Making use of opening-up reasoning modes

$$(Z_0) \wedge (Z_i) \wedge (Z_0 \oplus Z_i = (A \oplus A_i, c_0, c_0(A) \oplus c_0(A_i)) = Z_i')$$
$$\vdash Z_i', (i=1,2,\cdots,n)$$

Let

$$g_i' = (Z_i',\ c_{0t},\ c_{0t}(Z_i')) = (Z_i',\ c_{0t},\ 0.7 \oplus c_{0t}(A_i)) \triangleq (Z_i',\ c_{0t},\ x_i)$$

According to the definition of dependent function, there is $k(x_i) > 0$, that is

$$0.7 \oplus c_{0t}(A_i) - 1.8 > 0$$

so that $c_{0t}(A_i) > 1.1$. That is to say, we can look for an object A_i, which is over 1.1m high, to combine with monkey A to solve the incompatible problem.

For example, we can use Z_1=(estradeA_1,c_0,1.4m), Z_2=(chairA_2,c_0,0.5m), Z_3=(cabinetA_3,c_0,1.8m), Z_4=(tableA_4,c_0,1.2m),$\cdots$ to combine with A.

So we can make transformation

$$T_2 = \begin{bmatrix} add, & b_1, & g_0 \\ & b_2, & g_1 \\ & b_3, & g_0 \oplus g_1 \\ & b_4, & push\ \ A_1 \\ & b_5, & manual \\ & b_6, & beneath\ the\ bananas \end{bmatrix}$$

where the character b_4 expresses the mode of "*add*", b_5 expresses the tool and b_6 expresses the place. T_2 shows A pushes the table A_1 to the underside of the banana and stands on A_1, which is 1.4m high. At this time,

$$T_2 g_0 = g_0 \oplus g_1 = ((A\ , c_0, 0.5\text{m}), c_{0t}, 0.7m) \oplus ((A_1, c_0, 1.4\text{m}), c_{0t}, 1.4\text{m})$$
$$= ((A \oplus A_1, c_0,\ 1.9\text{m}), c_{0t}, 2.1\text{m})$$

$$K(T_2 g_0) = k(2.1) = 2.1 - 1.8 = 0.3 > 0$$

Now we have changed the incompatible problem to a compatible one.

Similarly, we can make transformations T_3, T_4, T_5, so that

$$K(T_3 g_0) = k(1.2) = 1.2 - 1.8 = -0.6 < 0$$
$$K(T_4 g_0) = k(2.5) = 2.5 - 1.8 = 0.7 > 0$$
$$K(T_5 g_0) = k(1.9) = 1.9 - 1.8 = 0.1 > 0$$

Apparently, T_4, T_5 can change the incompatible problem to a compatible one, but T_3 cannot.

It can be seen from the above case that through establishing the extension model of contradiction problems and using extended reasoning mode and extension transformation, we can get many transformations, such as T_1, T_2, T_4, T_5, for solving contradiction problems. But their degrees of superiority are not same. We must do superiority evaluation according to the feasibility(c_1), cost(c_2) and effect(c_3), and then select the transformations with higher superiority degree to put in practice. In this case, we can know the superiority degree of T_2, T_5 are higher through simulating in computer and superiority evaluation calculation. Limited to space, they are omitted.

6. CONCLUDING REMARKS

The objective of knowledge representation and knowledge reasoning is problem solving[7]. In this paper, through the approach to knowledge reasoning modes based on extended formulas, we attempt to apply them to solve contradiction problems, and the case analysis has proved it is feasible. The study will provide new tools for knowledge representation and knowledge reasoning of AI, and advance the study of knowledge reasoning.

Moreover, it will probe new ways for intelligentizing the process of solving contradiction problems.

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