Research on Contradiction Problem-Oriented Description Logic ALC_{D-ES}

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***Abstract*—The raise of extension set provides reasonable logical foundation for the automatic solving of contradiction problem. This paper views contradiction as an unsatiable concept, an unrealizable action or an item that can't meet the satisfaction of a certain concept, analyzes a representation language in face of contradiction problem, which is, a new extension description logic--ALC_{D-ES}. Syntax definition, semantic explanation and reasoning algorithm $Tableau_{D-ES}$ are given in details, which lay the theoretical foundation for the automatic solving method of contradiction problem based on extension description logic reasoning.**

***Index Terms*—extension set, description logic, contradiction problem, extenics**

I. INTRODUCTION

Contradiction problems exist everywhere in reality. In order to quantitatively describe the process of solving contradiction problem so as to realize its intelligent processing, Cai Wen from Guangdong University of Technology of China proposes a new subject-- Extenics, which crosses the field of mathematics and philosophy. In Extenics, quantitative tools are established based on extension set theory, including extension set, dependent function and extension relation. Developed from classical set and fuzzy set, extension set is used to quantitatively describe the process of "if it changes, it is not true. If no change, then true", so as to provide reasonable logic foundation for the automatic solving of contradiction problem[1]. However, in order to realize the intelligent processing of contradiction problem, a well-defined representation language and reasoning method need to be built. Consequently, this thesis will focus on a descriptive language which is suitable for describing contradiction problems and can automatically solve contradiction problems through automatic reasoning.

Description Logics (DLs) is a knowledge representation language with well-defined semantics and determinable reasoning method, it is widely used in semantic web [2]. At present, DLs occupy a position of importance in the research of Computer Science and Artificial Intelligence[3,4], the application of DLs is becoming more extensive, but along with it is that demands for the expressive power and inferential capability of description logic (DL) is getting higher and higher. The traditional description logic only describe the definite and static information, however there exists massive fuzzy information and dynamic information, therefore the traditional description logic should be extended.

At present, in order to make classic description logic express and process fuzzy knowledge, Straccia imported the fuzzy theory to expand DL ALC, proposed fuzzy DL FALC and provided a reasoning algorithm for it [5]. The most following fuzzy describe logics are obtained to strengthen expressive power based on it. The research results mainly contain FALCN[6], f-SHIN[7], f-SHOIN[8-9], FSHOIQ(D)[10], EFALCN[11], L-ALCN[12], F-SHOIQ(G)[13], f-OWL[14], $SHOIQ_{FC}$[15] and other vague description logics language, In addition, Z.M.MA summarized and analyzed the current fuzzy description logic[16]； For the sake of describing the dynamic information, Wolter introduced the dimension of dynamics in the concept description logic to express dynamic concept and relation, proposed a dynamic description logic[17]; Wang Ju presented the fuzzy dynamic description logic FDDL to deal with the fuzzy knowledge and dynamic knowledge[18]; Chang Liang presented a class of extended dynamic description logic named EDDL(X), which was improved from two aspects. On the one hand, the action in the dynamic description logic was interpreted as about the set of possible world sequences. On the other hand, the assertion of action process was introduced to the logic, which was described for the execution of actions[19]; WU Tao extended DDL indefinitely with cloud model, and proposed uncertainty dynamic description logic CDDL. The logic could effectively achieve the uncertainty static and dynamic knowledge representation and reasoning[20].

These description logic have the ability of describing fuzzy and dynamic information, but they take the classic set or fuzzy set as set theory foundation and can't describe the information with quantitative change and qualitative change, such as "not belong" to "belong", "not feasible" to "feasible" and other information. The author ever introduced static extension set in extenics[1] to

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replace classic set and fuzzy set to as the foundation of set theory, proposed a static extension description logic named $ALC_{S\text{-}ES}$ to describe the character of "having" or "not having" of things and the conception degree of "belong" or "not belong", but $ALC_{S\text{-}ES}$ cannot describe the variation of things[21]. Therefore, this paper introduces the "extensible variable T" to description logic $ALC_{S\text{-}ES}$ and puts forward a new extension description logic language $ALC_{D\text{-}ES}$, studies its syntax and semantics, and raises the general thoughts of solving contradiction problem through description logic $ALC_{D\text{-}ES}$..

II. Preliminaries

A. Extension Set

In order to describe dynamic classification of matter, extension set[1,2] which can describe the change ability of matters in a quantifiable way, is proposed based on classical set and fuzzy set to describe dynamic classification of matters. It offered the quantitative description method for solving process of contradiction problem. Extension set partition the set into positive region, negative region, zero boundary, extension region, stable region, Among it, extension region includes positive extension region and negative extension region, stable region includes positive stable region and negative stable region. The extension region is the core of the extension set, which is the most different characteristic contrasting classical set and fuzzy set.

Classical set theory uses two real numbers, 0 and 1, to describe whether a matter has a certain property or not, and fuzzy set theory uses a real number from [0, 1] to describe the degree at which a matter has a certain property. And extension set theory uses a real number from [-1, 1] to describe the degree at whether a matter has a certain property or not. A positive real number indicates the degree of having a property, while a negative real number indicates the degree of not having a property, and zero is boundary. Definition of extension set will be given next.

Definition 1 Given a discourse domain U, $T=(T_U, T_k, T_u)$ is three kinds of transformations in extension set, T_U represents the transformation of U, k is called dependent function, if for any element u in U, there is a corresponding real number $k(u) \in [-1, 1]$, T_k is the transformation of dependent function k, T_u is the transformation of element u We call

$$\tilde{A}(T) = \{(u, y, y') \mid u \in T_U U, y=k(u) \in [-1, 1], y'=T_k k(T_u u) \in [-1, 1]\}$$

an extension set in U. Where $y=k(u)$ is called a dependent function of $\tilde{A}(T)$, $k(u)$ is the correlative degree of u with regard to $\tilde{A}(T)$, $y'=T_k k(T_u u)$ is called a extension function of $\tilde{A}(T)$, the regulations is $y=k(u)<0$ when $u \in T_U U - U$.

$\tilde{A}(e) = \tilde{A} = \{(u, y) \mid u \in U, y=k(u) \in [-1, 1]\}$ when $T_U=e$, $T_k=e$, $T_u=e$, which is called static extension set, it can be divided into there parts:

$$A = \{(u, y) \mid u \in U, 1 \geq y=k(u) > 0\}$$

is called the positive region of $\tilde{A}$;

$$\bar{A} = \{(u, y) \mid u \in U, -1 \leq y=k(u) < 0\}$$

is called the negative region of $\tilde{A}$;

$$J_0 = \{(u, y) \mid u \in U, y=k(u)=0\}$$

is called the zero boundary of $\tilde{A}$.

The value of dependent function y'changed along with the U, k, u. supposing $T_U U=U$, when $T_U=e$, $T_k \neq e$, $T_u \neq e$, then

$$A_+(T) = \{(u, y, y') \mid u \in U, -1 \leq y=k(u) \leq 0, y'=0 < T_k k(T_u u) \leq 1\}$$

is called the positive extension region of $\tilde{A}(T)$;

$$A_-(T) = \{(u, y, y') \mid u \in U, y=0 < k(u) \leq 1, y'=-1 \leq T_k k(T_u u) \leq 0\}$$

is called the negative extension region of $\tilde{A}(T)$;

$$A_+(T) = \{(u, y, y') \mid u \in U, y=0 < k(u) \leq 1, y'=0 < T_k k(T_u u) \leq 1\}$$

is called the positive stable region of $\tilde{A}(T)$;

$$A_-(T) = \{(u, y, y') \mid u \in U, y=-1 \leq k(u) \leq 0, y'=-1 \leq T_k k(T_u u) \leq 0\}$$

is called the negative stable region of $\tilde{A}(T)$.

Similarly extension region and stable region also exits when $T_U \neq e$.

The extension region is the core of the extension set, some elements can possess a property which is not possessed inborn after extension transformation (including the transformation of element, the transformation of dependent function and the transformation of discourse domain). Obviously, different transformation corresponds to different extension region. Extension region can be the theoretical foundation of transferring contradiction problem into no contradiction.

B. Description Logic

Description logic [3]is based on the concept and role. The concept denotes sets of individuals, and the role denotes relationship between individuals, which is a duality relation of the domain set.

There are four components in DL system (DLs): 1) constructors for building complex concepts and roles; 2) TBox; 3) ABox; 4) reasoning rules of the TBox and ABox. The DLs expression ability and reasoning ability are decided by the selections of above several factors and different assumptions.

The traditional DL contains a lot of categories. Elementary descriptions consist of atomic concepts and atomic roles. Complex descriptions can be built from them inductively with concept constructors. In abstract notations, we use the letters A and B for atomic concepts, the letter P for atomic roles, and the letters C and D for concept descriptions. Description languages are distinguished by the constructors they provide. Use I to stand for a interpretation, then Table 1 can be used to account for the syntax and semantics of ALC.

TABLE 1
ALC'S SYNTAX AND SEMANTICS

constructor	syntax	semantics
atomic concept	A	$A^I \sqsubseteq \Delta^I$
atomic role	P	$P^I \sqsubseteq \Delta^I \times \Delta^I$
universal concept	$\top$	Δ^I
bottom concept	$\bot$	$\varnothing$
atomic negation	$\neg A$	$\Delta^I - A^I$
concept negation	$\neg C$	$\Delta^I - C^I$
concept union	$C \sqcup D$	$C^I \sqcup D^I$
concept intersection	$C \sqcap D$	$C^I \sqcap D^I$
existential quantification	$\exists R.C$	$\{x \mid \exists y,(x,y) \in R^I \wedge y \in C^I\}$
value restriction	$\forall R.C$	$\{x \mid \forall y,(x,y) \in R^I \Rightarrow y \in C^I\}$

A description logic knowledge base K=<T, A> is constituted by two parts: TBox T and ABox A. TBox is a finite set of inclusion assertions and has the form $C \sqsubseteq D$ ($R \sqsubseteq S$) or $C \equiv D$ ($R \equiv S$),where C, D are concepts (R, S are roles). Axioms of the first kind are called inclusions, while axioms of the second kind are called equalities. ABox is a finite set of instance assertions and has the form $C(a)$ or $R(b, c)$, where C is a concept .where a, b, c are individuals and R is a relation. By the first kind, called concept assertions, one states that a belongs to (the interpretation of) C, by the second kind, called role assertions, one states that b, c are fillers of the role R.

III. DESCRIPTION LOGIC $ALC_{D\text{-}ES}$

Description logic $ALC_{D\text{-}ES}$ takes static extension set as the set theory foundation. Although it shows fuzzy information according to the degree of belonging, it does not have the ability to describe dynamic knowledge. Therefore, individuals in the negative domain cannot be changed into positive domain. Solving contradiction problem, however, is a transformation process from infeasibility to feasibility, unsatisfaction to satisfaction. If the contradiction factors cannot be transformed by action, contradiction problems cannot be settled. Consequently, extension transformation T is introduced to describe the strategy of solving contradiction problems. The syntax and semantics of DL $ALC_{D\text{-}ES}$ are given in details in the following part.

A. The syntax of $ALC_{D\text{-}ES}$

The Description logic $ALC_{D\text{-}ES}$ adds the extension transformation T on the basis of $ALC_{S\text{-}ES}$ to describe the variability of domain individual and the procedure of quantitative change and qualitative change. The following will be given the related definition of the syntax of $ALC_{D\text{-}ES}$.

Definition 2 The concept of $ALC_{D\text{-}ES}$

(1)The full concept $\top$, the empty concept and the atomic concept A are all the concept of $ALC_{D\text{-}ES}$;

(2)IF C and D are concept of $ALC_{D\text{-}ES}$, then ($C \sqcap D$), ($C \sqcup D$) and ($\neg C$) are all the concept of $ALC_{D\text{-}ES}$;

(3)IF C is the concept of $ALC_{D\text{-}ES}$, R is the role, Then $\forall R.C$、$\exists R.C$ are all the concept of $ALC_{D\text{-}ES}$;

(4)IF C is the concept of $ALC_{D\text{-}ES}$, T_k *is* extension transformation, Then$[T_k]$ C is concept.

Here, $[T_k]C$ represents the transformation to the evaluation criterion of the concept C and shows the genetic quantitative change and qualitative change of correlative degree of the element in the Extension Set to which the concept C corresponds.

For instance, C represents qualified students, T_k represents lowering the enrollment mark. Then $[T_k]C$ means the degree of individuals in the discourse domain which belong to qualified students has changed. It is the essence of the concept that has changed, not the individual itself.

Definition 3 The role of $ALC_{D\text{-}ES}$

(1)The atomic role R is the role of $ALC_{D\text{-}ES}$;

(2)IF R is the role of $ALC_{D\text{-}ES}$, T_k is extension transformation, Then $[T_k]R$ is the role of $ALC_{D\text{-}ES}$.

Here, $[T_k]R$ represents the transformation to the evaluation criterion of the role R and shows the change of correlative degree of the element in extension binary role to which the role R corresponds.

Definition 4 Extension transformation(T)

(1)Atomic transformation T is the extension transformation of $ALC_{D\text{-}ES}$;

(2)IF T is the extension transformation of $ALC_{D\text{-}ES}$, Then T^- is the extension transformation of $ALC_{D\text{-}ES}$, "$^-$" is the inverse operator of extension transformation, which represents the inverse transformation of T. For any extension transformation of $ALC_{D\text{-}ES}$, there exists its inverse transformation;

(3)IF T_1 and T_2 are extension transformation of $ALC_{D\text{-}ES}$, Then $T_1 \sqcup T_2$ is the extension transformation of $ALC_{D\text{-}ES}$, "$\sqcup$" is the product operator of extension transformation, it represents executing the transformation T_1 and the transformation T_2 in sequence.

The extension transformation T can be T_k or T_u, and it satisfies:

$$(T_1 \sqcup T_2)^- = (T_2^-) \sqcup (T_1^-)$$

$$[T^-] \sqcup [T]\, C(a) = C(a)$$

$$[T^-] \sqcup [T]\, R(a, b) = R(a, b)$$

Among them, $[T]\ C(a)$ can be $[T_k]\ C(a)$, $C(T_a\ a)$ or $[T_k]\ C(T_a\ a)$, T_a is the transformation of the invidual a. Simultaneously, $[T]\ R(a, b)$ can be $[T_k]\ R(a, b)$, $R(T_a a, T_b b)$ or $[T_k]R(T_a a, T_b b)$. Definiting the product of extension transformation is due to the solution of contradiction problems needs to continueously executing several actions.

Definition 5 The operator "$^-$" have symmetry. In order to avoid the occurrence of T^{--}, we definite the function *Inv* to return the inverse of the transformation.

$$Inv(T)=\begin{cases}T^{-} & \text{if } T\neq T_1^{-}\\ T_1 & \text{otherwise, if } T=T_1^{-}\end{cases}$$

Definition 6 The describe form of Extension transformation(T) of describe logics $ALC_{D\text{-}ES}$

In extenics, the Extension transformation(T) is described as:

$$T=\begin{bmatrix} T,\ \textit{operational objectives},\ x1,\dots\dots,xn \\ \textit{premise condition},\quad PT \\ \textit{transformation result},\quad ET \\ \dots\dots\ \dots\dots \end{bmatrix}$$

The Extension Transformation(T) = $T_k \cup T_u$. Among them, the operational objectives of T_k is the concept or role of $ALC_{D\text{-}ES}$, but the operational objectives of T_u is the individual of $ALC_{D\text{-}ES}$, it can be single individual or a class of individual that satisfy certain condition; P_T is the related concept and role or concept assertion and role assertion between pre-implement of the transformation T and the operational objectives; E_T is the transformation result of the related concept and role or concept assertion and role assertion that executing the transformation T causes.

Definition 7 Knowledge base DEK of $ALC_{D\text{-}ES}$ is defined as $DEK=<T_{D\text{-}ES}, A_{D\text{-}ES}>$. Among it, $T_{D\text{-}ES}$ is the TBox of $ALC_{D\text{-}ES}$, $A_{D\text{-}ES}$ is the ABox of $ALC_{D\text{-}ES}$, and it satisfies:

(1)$T_{D\text{-}ES}$ is the set composed of inclusion axiom "$\sqsubseteq$" and equivalent axiom "$\equiv$" of the concept or extension transformation in $ALC_{D\text{-}ES}$, its form is as follows:

① $C \sqsubseteq D$, $C \equiv D$, here C and D are the concept of $ALC_{D\text{-}ES}$, $C \equiv D$ if and only if $C \sqsubseteq D$ and $D \sqsubseteq C$;

② $T_1 \sqsubseteq T_2$、$T_1 \equiv T_2$, here T_1 and T_2 are the extension transformation of $ALC_{D\text{-}ES}$, $T_1 \equiv T_2$ if and only if $T_1 \sqsubseteq T_2$ and $T_2 \sqsubseteq T_1$.

(2)$A_{D\text{-}ES}$ is composed of concept assertion and role assertion,ψ is composed of (a, ψ, ψ') and ((a, b), ψ, ψ'). Among it, a and b are all inviduals,ψ denotes the known state of the domain individual, that is the individual's related assertion before transformation, ψ' denotes the related assertion of the individual that maybe exist after the transformation of T_k or T_u. The form of $A_{D\text{-}ES}$ is as follows:

① $<\pi\geq n>$, $<\pi>n>$, $<0<\pi\leq m>$, $<0<\pi<m>$
($0<n\leq 1$, $0<m<1$)

② $<0\geq\pi\geq n>$, $<0\geq\pi>n>$, $<\pi\leq m>$, $<\pi<m>$
($-1\leq n<0$, $-1<m\leq 0$)

③ $<\pi\leq n>$, $<\pi<n>$, $<\pi\geq m>$, $<\pi>m>$
($0<n\leq 1$, $-1\leq m\leq 0$)

π denotes $[T_k]C(T_a a)$ or $[T_k]R(T_a a,\ T_b b)$,which represents the degree in which individual $T_a a$ belongs to concept $[T_k]C$ or individual $T_a a$ and $T_b b$ belong to role $[T_k]R$. Amont them, T_k, T_a and T_b can be empty transformation.

In the Assertion Set, it records many kinds of transformation concerning different concept, role and individual. So directed towards different problems, it can provide kinds of possible transformation to solve them.

B. The Semantics of $ALC_{D\text{-}ES}$

The semantics of $ALC_{D\text{-}ES}$ is given according to the semantic explanation of extension set and the semantics explanation method of classical description logic.

Define an extension explanation DEI=(Δ^{DEI}, $\cdot^{DEI}$), ". Δ^{DEI}" is an individual set that is not empty, is the discourse domain of explanation. $\cdot^{DEI}$ is an extension explanation function.

The following will separately give the semantics explanation of the concept and role of $ALC_{D\text{-}ES}$, TBox axiom, ABox assertion and so on.

1) The semantic explanation of concept and role in $ALC_{D\text{-}ES}$ is as follows:

(1) Full concept $\top$: $\top^{DEI}(a)$=1, among it, $a \in \Delta^{DEI}$ which is a individual and the following a has the same meaning.

(2) Empty concept $\perp$: $\perp^{SEI}(c)$= -1;

(3) Any concept C: the explanation function $\cdot^{DEI}$ make C map to an extension set $C(T)$ on discourse domain Δ^{DEI}:

$$C(T)=\{(a,y,y')\mid a^{DEI}\in\Delta^{DEI}, y=k(a), y'=T_k k(T_a a)\}$$

Here a represents individual, k represents the dependent function of C, and T consists of T_k and T_a. T_k represents the transformation of dependent rule of concept and T_a represents the transformation of individual a in the discourse domain. y in $C[T]$ aims to make a record of the the degree that element belongs to a certain concept or relation during the transformation of T. y' is dependent degree value. According to different transformation, semantic explanation of concept C is divided into the following aspects.

① When $T_k=e$ and $T_a=e$, $y = y'$. Explanation function $\cdot^{DEI}$ maps C as a dependent function, namely, C^{DEI}: $\Delta^{DEI}\rightarrow[-1, 1]$.

② When $T_k\neq e$ and $T_a=e$, $C[T]=\{(a,y,y')\mid a^{DEI}\in\Delta^{DEI}, y=k(a), y'=T_k k(a)\}$.

According to the correlation value that the element in discourse domain Δ^{DEI} belongs to this extension set before and after the transformation, it divides the elements in discourse domain into four region: the positive extension region $\dot{C}_{+}(T)$, the negative extension region $\dot{C}_{-}(T)$, the positive stable region $C_{+}(T)$, the negative stable region $C_{-}(T)$, So the concept$[T_k]$ C is explained by $\cdot^{DEI}$ as:

$$\dot{C}_{+}(T)=\{(a,y,y')\mid a\in\Delta^{DEI}, y=-1\leq k(a)\leq 0, y'=0<T_k k(a)\leq 1\};$$

$$\dot{C}_{-}(T)=\{(a,y,y')\mid a\in\Delta^{DEI}, y=0<k(a)\leq 1, y'=-1\leq T_k k(a)\leq 0\};$$

$$C_{+}(T)=\{(a,y,y')\mid a\in\Delta^{DEI}, y=0<k(a)\leq 1, y'=0<T_k k(a)\leq 1\};$$

$$C_{-}(T)=\{(a,y,y')\mid a\in\Delta^{DEI}, y=-1\leq k(a)\leq 0,$$

$$y'=-1\le T_k k\,(a)\le 0\}.$$

③ When $T_k=e$ and $T_a\ne e$, $C[T]=\{(a, y, y')\mid a^{DEI}\in\Delta^{DEI}, y=k\,(a), y'=k\,(T_a\,a)\}$.

According to the change of the dependent degree value which elements in the discourse domain Δ^{DEI} belong to the extension set during transformation, concept $ALC_{D\text{-}ES}$-C is explained as follows.

$$\underset{\cdot}{C}_{+}(T)=\{(a, y, y')\mid a\in\Delta^{DEI}, y=-1\le k\,(a)\le 0,$$
$$y'=0<k\,(T_a\,a)\le 1\};$$
$$\underset{\cdot}{C}_{-}(T)=\{(a, y, y')\mid a\in\Delta^{DEI}, y=0<k\,(a)\le 1,$$
$$y'=-1\le k\,(T_a\,a)\le 0\};$$
$$C_{+}(T)=\{(a, y, y')\mid a\in\Delta^{DEI}, y=0<k\,(a)\le 1,$$
$$y'=0<k\,(T_a\,a)\le 1\};$$
$$C_{-}(T)=\{(a, y, y')\mid a\in\Delta^{DEI}, y=-1\le k\,(a)\le 0,$$
$$y'=-1\le k\,(T_a\,a)\le 0\}.$$

④ When $T_k\ne e$ and $T_a\ne e$, then $C[T]=\{(a, y, y')\mid a^{DEI}\in\Delta^{DEI}, y=k\,(a), y'=T_k k\,(T_a\,a)\}$.

According to the the change of the dependent degree value which T_k and T_a belong to the extension set during transformation, $[T_k]C$ is explained as follows.

$$\underset{\cdot}{C}_{+}(T)=\{(a, y, y')\mid a\in\Delta^{DEI}, y=-1\le k\,(a)\le 0,$$
$$y'=0<T_k k\,(T_a\,a)\le 1\};$$
$$\underset{\cdot}{C}_{-}(T)=\{(a, y, y')\mid a\in\Delta^{DEI}, y=0<k\,(a)\le 1,$$
$$y'=-1\le T_k k\,(T_a\,a)\le 0\};$$
$$C_{+}(T)=\{(a, y, y')\mid a\in\Delta^{DEI}, y=0<k\,(a)\le 1,$$
$$y'=0<T_k k\,(T_a\,a)\le 1\};$$
$$C_{-}(T)=\{(a, y, y')\mid a\in\Delta^{DEI}, y=-1\le k\,(a)\le 0,$$
$$y'=-1\le T_k k\,(T_a\,a)\le 0\}.$$

The semantic explanation of $ALC_{D\text{-}ES}$-concept above reveals that different transformation of the same concept can lead to different results and different semantic explanation.

(4) Any role of $ALC_{D\text{-}ES}$ R: the explanation function $\cdot^{DEI}$ make R map to an extensible binary role on discourse domain Δ^{DEI}:

$$R(T)=\{((a, b), y, y')\mid a^{DEI}\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=k(a, b), y'=T_k k(T_a\,a, T_b\,b)\}$$

Among it, a, b denotes individual, k denotes the correlation function of R, T contains T_k, T_a and T_b, T_k denotes the transformation to the correlation rule of R, T_a and T_b denote the transformation to individual a and individual b in discourse domain.

According to different transformation, the semantic explanation of role R can be divided into the following aspects.

① When $T_k=e$, $T_a=e$ and $T_b=e$, $y=y'$, then as to role R, explanation function $\cdot^{DEI}$ maps R as a dependent function, namely, R^{DEI}： $\Delta^{DEI}\times\Delta^{DEI}\to[-1, 1]$.

② When $T_k\ne e$, $T_a=e$ and $T_b=e$ 时, then $R\,[T]=\{((a, b), y, y')\mid a^{DEI}\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI}, y=k(a, b), y'=T_k k(a, b)\}$.

Same with $C(T)$, it divides $R(T)$ into four region: the positive extension region $\underset{\cdot}{R}_{+}(T)$, the negative extension region $\underset{\cdot}{R}_{-}(T)$, the positive stable region $R_{+}(T)$, the negative stable region $R_{-}(T)$, So the role $[T_k]R$ is explained by $\cdot^{DEI}$ as:

$$\underset{\cdot}{R}_{+}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=-1\le k\,(a, b)\le 0, y'=0<T_k k\,(a, b)\le 1\};$$
$$\underset{\cdot}{R}_{-}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=0<k\,(a, b)\le 1, y'=-1\le T_k k\,(a, b)\le 0\};$$
$$R_{+}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=0<k(a, b)\le 1, y'=0<T_k k\,(a, b)\le 1\};$$
$$R_{-}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=-1\le k(a, b)\le 0, y'=-1\le T_k k\,(a, b)\le 0\}.$$

③ When $T_k=e$, $T_a\ne e$ and $T_b=e$, then

$$R[\mathrm{T}]=\{((a, b), y, y')\mid a^{DEI}\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=k\,(a, b), y'=k\,(T_a\,a, b)\}.$$

Also$R[T]$ is divided into four domains.

$$\underset{\cdot}{R}_{+}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=-1\le k\,(a, b)\le 0,\ y'=0<k\,(T_a\,a, b)\le 1\};$$
$$\underset{\cdot}{R}_{-}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=0<k\,(a, b)\le 1,\ y'=-1\le k\,(T_a\,a, b)\le 0\};$$
$$R_{+}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=0<k\,(a, b)\le 1, y'=0<k\,(T_a\,a, b)\le 1\};$$
$$R_{-}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=-1\le k\,(a, b)\le 0, y'=-1\le k\,(T_a\,a, b)\le 0\}.$$

In addition, when $T_k=e$, $T_a=e$ and $T_b\ne e$, as well as when $T_k=e$, $T_a\ne e$ and $T_b\ne e$, the situation is analogous.

④ When $T_k\ne e$, $T_a\ne e$ and $T_b\ne e$, $R[\mathrm{T}]=\{((a, b), y, y')\mid a^{DEI}\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI}, y=k\,(a, b), y'=T_k k\,(T_a\,a, T_b\,b)\}$.

Also$R[T]$ is divided into four domains.

$$\underset{\cdot}{R}_{+}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=-1\le k\,(a, b)\le 0, y'=0<T_k k\,(T_a\,a, T_b\,b)\le 1\};$$
$$\underset{\cdot}{R}_{-}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=0<k\,(a, b)\le 1,\ y'=-1\le T_k k\,(T_a\,a, T_b\,b)\le 0\};$$
$$R_{+}(T)=\{((a, b), y, y')\mid a\in\Delta^{DEI}, b^{DEI}\in\Delta^{DEI},$$
$$y=0<k(a, b)\le 1, y'=0<T_k k\,(T_a\,a, T_b\,b)\le 1\};$$

$R_{-}(T) = \{((a, b), y, y') \mid a \in \Delta^{DEI}, b^{DEI} \in \Delta^{DEI},$
$y = -1 \leq k(a, b) \leq 0, y' = -1 \leq T_k k(T_a a, T_b b) \leq 0\}.$

In the following explanation, C and D represents $ALC_{D\text{-}ES}$- concept, R represents $ALC_{D\text{-}ES}$-role, a represents individual in the discourse domain, T_k and T_k' represents the transformation of the dependent function of concept or relation, which can also be empty transformation.

⑤ $([T_k]C \sqcap [T_k']D)^{DEI}(a) = (a, \min\{C^{DEI}(a), D^{DEI}(a)\}, \min\{[T_k]C^{DEI}(a), [T_k']D^{DEI}(a)\})$.

⑥ $([T_k]C \sqcup [T_k']D)^{DEI}(a) = (a, \max\{C^{DEI}(a), D^{DEI}(a)\}, \max\{[T_k]C^{DEI}(a), [T_k']D^{DEI}(a)\})$.

⑦ $(\neg[T_k]C)^{DEI}(a) = (a, -C^{DEI}(a), -[T_k]C^{DEI}(a))$.

⑧ $(\forall[T_k]R.\ [T_k']C)^{DEI}(a) = (a, \inf_{b \in \Delta^{DEI}}\{\max\{\sim R^{DEI}(a, b), C^{DEI}(b)\}\}, \inf_{b \in \Delta^{DEI}}\{\max\{\sim [T_k]R^{DEI}(a, b), [T_k']C^{DEI}(b)\}\})$.

⑨ $(\exists[T_k]R.\ [T_k']C)^{DEI}(a) = (a, \sup_{b \in \Delta^{DEI}}\{\min\{R^{DEI}(a, b), C^{DEI}(b)\}\}, \sup_{b \in \Delta^{DEI}}\{\min\{[T_k]R^{DEI}(a, b), [T_k']C^{DEI}(b)\}\}$.

(2) The semantic explanation of the $ALC_{D\text{-}ES}$'s TBox axiom is as follows:

① Inclusion Axiom $C \sqsubseteq D$ is explained as: for $\forall a \in \Delta^{DEI}$, there exists $C^{DEI}(a) \leq D^{DEI}(a)$;

② Equivalence Axiom $C \equiv D$ is explained as: for $\forall a \in \Delta^{DEI}$, there exists $C^{DEI}(a) = D^{DEI}(a)$;

③ If T_{k1} and T_{k2} are all the correlation rule transformation of $ALC_{D\text{-}ES}$ concept, Then regarding to Inclusion Axiom $T_{k1} \sqsubseteq T_{k2}$, it is explained as: for $\forall a \in \Delta^{DEI}$, there exists $([T_{k1}]C)^{DEI}(a) \leq ([T_{k2}]C)^{DEI}(a)$;

④ If T_{k1} and T_{k2} are all the correlation rule transformation of $ALC_{D\text{-}ES}$ concept, Then regarding to Equivalence Axiom $T_{k1} \equiv T_{k2}$, it is explained as: for $\forall a \in \Delta^{DEI}$, there exists $([T_{k1}]C)^{DEI}(a) = ([T_{k2}]C)^{DEI}(a)$;

⑤ If T_{u1} and T_{u2} are the individual transformation in $ALC_{D\text{-}ES}$, and their forms are $T_{u1}(x_1, \ldots, x_n) \equiv (P_{Tu1}, E_{Tu1})$ and $T_{u2}(x_1, \ldots, x_n) \equiv (P_{Tu2}, E_{Tu2})$ respectively, Then for inclusion axiom $T_{u1} \sqsubseteq T_{u2}$, it is explained as: for any same individual instance, there exists $P_{Tu1}{}^{DEI} \geq P_{Tu2}{}^{DEI}$, $E_{Tu1}{}^{DEI} \leq E_{Tu2}{}^{DEI}$, here P_{Tu2}, P_{Tu1}, E_{Tu1} and E_{Tu2} are the assertion about individual instance;

For example: $T_{a1}(a) \equiv (P_{Ta1}, E_{Ta1})$, among it P_{Ta1} denotes $C(a) \leq 0$, E_{Ta1} denotes $C(a) \geq 0.8$.In addition, there exists $T_{a2}(a) \equiv (P_{Ta2}, E_{Ta2})$, among it P_{Ta2} denotes $C(a) \leq -0.2$, E_{Ta2} denote $C(a) \geq 0.9$, then $T_{a1} \sqsubseteq T_{a2}$.

⑥ If T_{u1} and T_{u2} are the same as ⑤, Then regarding to equivalence axiom $T_{u1} \equiv T_{u2}$, it is explained as: for any same individual instance, there exists $P_{Tu1}{}^{DEI} = P_{Tu2}{}^{DEI}$, $E_{Tu1}{}^{DEI} = E_{Tu2}{}^{DEI}$.

(3) The form of semantic explanation of Abox in $ALC_{D\text{-}ES}$ is the same as it in $ALC_{S\text{-}ES}$.

According the semantic explanation method above-mentioned, the concept, role, Tbox axiom, Abox assertion and the satisfiability of Knowledge Base $ALC_{D\text{-}ES}$ *DEK* can be defined likes they are in $ALC_{S\text{-}ES}$.

C. The Basic Reasoning Problems of $ALC_{D\text{-}ES}$

The basic reasoning problems of the description logic $ALC_{D\text{-}ES}$ mainly contain the satisfiability of concept, the inclusion relation of concept, the consistency checking for the instance assertion set and so on. These problems can be transformed as the consistency checking problem of the instance assertion set. This paper adds the rule of extension transformation T based on the consistency checking algorithm $\text{Tableau}_{S\text{-}ES}$ of the $ALC_{S\text{-}ES}$, proposes a new consistency checking algorithm $\text{Tableau}_{D\text{-}ES}$ of the instance assertion set, and explains the algorithm's executing process by instance.

The consistency reasoning algorithm of the assertion set ABox $A_{D\text{-}ES}$ in $ALC_{D\text{-}ES}$ is given below.

Algorithm. The consistency reasoning algorithm $\text{Tableau}_{D\text{-}ES}$.

Input: ABox $A_{D\text{-}ES}$.

Output: Boolean Value.

(1)The following rules are used to extend any assertion in ABox $A_{D\text{-}ES}$ until no rule can be used.

① The rules whose form is the same to it of all the algorithm rules in $\text{Tableau}_{S\text{-}ES}$[21], only the objectives the symbol represents in the rules are different. For example, in the rule of $\text{Tableau}_{D\text{-}ES}$ algorithm, C and D denote the concept of $ALC_{D\text{-}ES}$, it can contain the form of $[T_k]C$ and $[T_k']D$, a and b denote the individual of $ALC_{D\text{-}ES}$, they can contain the form of $T_a a$ and $T_b b$.

② The rule of T_k is an new rule added in $\text{Tableau}_{D\text{-}ES}$.

If T_k is the transformation to the correlation rule of the concept C, Then there exists:

$([T_k](\neg C))(a) = (\neg[T_k]C)(a)$
$([T_k](C \sqcap D))(a) = ([T_k]C \sqcap D)(a)$
$([T_k](C \sqcup D))(a) = ([T_k]C \sqcup D)(a)$
$([T_k](\exists R.C))(a) = (\exists R.\ [T_k]C)(a)$
$([T_k](\forall R.C))(a) = (\forall R.\ [T_k]C)(a)$

If T_k' is the transformation to the correlation rule of the relation R, Then there exists:

$([T_k'](\exists R.C))(a) = (\exists[T_k']R.\ C)(a)$
$([T_k'](\forall R.C))(a) = (\forall[T_k']R.\ C)(a)$

(2)Check whether $A_{D\text{-}ES}$ contains the conflict , if there is no conflict, then $A_{D\text{-}ES}$ is consistent, otherwise $A_{D\text{-}ES}$ is inconsistent.

Algorithm ends.

IIV. SOLVING WAY OF CONTRADICTION PROBLEM BASED ON $ALC_{D\text{-}ES}$

The automatic solving of contradiction problem can be transformed as a basic reasoning process of the unsatiable concept or unrealizable action. The way of research is as follows.

As to the insatiable concept, it can be regarded that none of the dependent degree value of element can be over 0. If there exists an assertion in the knowledge base *DEK* that the transformation of T_k and T_u can satisfy the concept, then T_k and T_u can be the strategy of solving that problem.

(1) For instance, C=qualified staff, if there does not exist any individual a_i in the discourse domain that made $C(a_i)$>0, but T_k =lowering qualification and T_{a1} =improving a_i's vocational skills, and $[T_k]C(a_1)$ >0.3, $C(T_{a1}\ a_1)$ > 0.6, $[T_k]C(T_{a1}\ a_1)$ > 0.95 in the discourse domain. Then the unsatiable concept C can be made satiable by the extension transformation of T_k and T_{a1}. Consequently, T_k and T_{a1} can be the strategy of solving that problem.

(2) As to the individual a which can not satisfy a certain concept C, we can search if there is a T_a transformation in the knowledge base *DEK* that made $C(T_a\, a)$ >0. If there is, T_a can be a strategy of solving that problem.

(3) As to an unrealizable action, the solving method can be transferred to solving the unsatiable concept or an item that can't meet the satisfaction of a certain concept in an extension transformation.

T_k or T_u can be the inverse transformation of a certain transformation or the product of several transformations.

Therefore, the automatic solving of contradiction problem can be realized by analyzing the basic reasoning algorithm of DL $ALC_{D\text{-}ES}$ such as the satiability of concepts, the inclusion relation of concepts and the consistency checking for ABox.

V. Conclusion

In order to describe contradiction problem and realize its automatic solving, on the basis of Classical DL ALC, this thesis introduces extension set and extension transformation, raises new DL $ALC_{D\text{-}ES}$, describes its syntax and semantics and analyzes general solving method of contradiction problem. $ALC_{D\text{-}ES}$ can not only describe fuzzy knowledge, but also depict the process of quantitative and qualitative changes, so as to provide well-defined description language and automatic solving strategy for contradiction problem.

The following research will focus on the basic reasoning algorithm of DL $ALC_{D\text{-}ES}$, prove its reliability, terminability and decidability, so as to realize the automatic solving of contradiction problem.

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