Extension theory and its application

CAI Wen

Research Institute of Matter-Element Analysis, Guangdong University of Technology, Guangzhou 510090, *China*

Abstract The article *Extension Set and Non-compatible Problems* was published in 1983. It proclaimed the birth of extension theory. Its objects of study are contradictory problems in the realistic world; its theoretical pillars are matter element theory and extension set theory. Its basic methods are extension methods. Its practical methods are extension engineering methods, including the extension information method, extension system method and extension decision method, etc. Basic theory, practical method and application of extension theory in economy, management, control and artificial intelligence will be introduced.

Keywords: extension theory, matter element, extension set.

IN practice, there are many problems where goals and conditions are contradictory. For example, it is impossible to weigh an elephant about 5 000 kg by using a steelyard, whose limit is 200 kg; to solve complicated cases just by a little information; to design complicated new products just according to a little demand for functions; to connect two opposite traffic systems that the vehicles are driven on the left of the road in one traffic system and are driven on the right in another one, etc. These problems exist everywhere in our daily lives, and the human society advances ceaselessly in coping with all these problems. Therefore a natural question comes out that how we can find the general method to solve these problems, which are exactly the study objectives of extension theory called contradictory problems. The contradictory problems can be classified into three subclasses: contradictory problem between subjective goals and objective conditions, contradictory problem between subjective goals and contradictory problem between objective goals. Refs. [1,2] put forward a new research field to solve contradictory problems by formalization method.

It is impossible for one to solve contradictory problems just considering the quantitative relation. In the famous ancient Chinese story "Prince Caochong weighs an elephant", if Prince Caochong had only considered the quantitative relation in weighing an elephant, he would not have solved the problem, but he succeeded by turning the weight of the elephant into the same weight of stones. The stones can be weighed by parts, so this problem was easily solved. The key for solving this problem is the transformation which turns elephant into stones. This is what we call the matter transformation. In order to move a cupboard into a house, of which the door is shorter than the cupboard, we usually use the method of laying it down on its side. The key here is turning the contradiction between the height of the cupboard and that of the door into a compatible relation between the length of the cupboard and the height of the door.

To solve contradictory problems, it is not enough only considering the quantitative relation, we must consider the matter, the characteristics and their measure together. Moreover, we must consider their relation and their change. In ref. [1], the concept of matter-element was given, which is the logic cell of extenics and puts the matter, the characteristic and their measure together into consideration.

Extensibility is the basis to solve contradictory problems. We have to open up things in order to solve contradictory problems. The possibility for opening up things is called extensibility of things, and the opening-up carried out is called extension. The extensibility of things can be described by that of matter-element.

In order to solve contradictory problems, we must study the transformation which turns one thing that does not have property P into another which has the property P. The concept of extension set was given in ref. [1] too, which can describe this kind of transformation quantitatively. The extension field is a set of things which does not have the property P but can be changed into those with the property P.

Extension theory is a new kind of knowledge system based on the concepts of matter-element and extension set. Its subject selection began in 1976, and its initiative paper was published in 1983. It was the stage for generating knowledge of extension theory from 1983 to 1992. By far, the primary frame of

extension theory has been set up with the effort of many researchers[1—6].

Matter-element theory and the theory of extension set are two theoretical pillars of extension theory, the hard core of extension theory. The former studies matter-element and its transformations. The latter is the quantitative tool of extension theory. The combination of these two pillars with other science generates the respective knowledge, which is the soft part of extension theory.

Based on extension theory, a series of particular extension methods have been developed, such as matter-element extension method, matter-element transformation method and optimal appraisal method[6]. The combination of extension methods with other engineering fields generates the respective extension engineering methods. The formalization tools to solve contradictory problems have been set up in refs. [1—6], which include qualitative tools and quantitative tools.

Since 1993, extension theory has been coming into the stage of spreading knowledge, which is marked by the work of training research scholars. And during 1983—1992, some researchers through the combination of extension theory with the professional knowledge of other research fields have developed the primary application. The application technology of extension theory is called extension engineering[3].

Extension theory makes it possible to develop the formalized description for activities of creative thinking, such as knowledge innovation, new products designing and strategy generating. With the combination of extension theory with management science, cybernetics, information science and computer science, extension engineering methods have been applied to some engineering fields such as economic engineering, management engineering, decision process and process control. Now extension theory has been entering into the research fields of artificial intelligence and its relevant sciences.

1 Concepts and theory

1.1 Matter-element theory

In the real world, things are entity of quality and quantity. The quantitative change and qualitative change of one thing are interrelated closely and interact on each other. Classical mathematics consider only the quantity and forms of objects, it studies quantitative relation and spatial forms. As a result, classical mathematics has its limitation in dealing with contradictory problems, which is associated with the qualitative change.

Extension theory can be used to describe the thinking process associated with both quantitative change and qualitative change. Extension theory regards the objective world as a world of matter-element, so the contradictory problems in the real world can be transformed into those among matter-elements.

1.1.1 Matter-element. We use an ordered triad

$$R = (N, c, \nu)$$

as the basic element for describing things, called matter-element, where N represents the matter; c, the characteristics; ν is the N's measure about the characteristic c; the expression $\nu = c(N)$ describes the relation between quality and quantity.

The concept of characteristic-element $M(c, \nu)$ was introduced in ref. [9], which is composed of the characteristic c and respective measure ν. It can be used to describe the characteristics of things. A matter has many characteristic-elements, which can be described by n-dimensional matter-elements

$$R = \begin{pmatrix} N, & c_1, & v_1 \\ & c_2, & v_2 \\ & \cdots & \cdots \\ & c_n, & v_n \end{pmatrix}.$$

And the dynamic matter-element $R(t) = (N(t), c, \nu(t))$ describes the change of matter N with time. The concept of affair-element is introduced in ref. [10]. We use an ordered triad

$$I = (d, h, u)$$

as the basic element for describing affairs, called affair-element, where d is the verb; h, the characteristic, including the subjects of the verb, the objects, the time, the places, the tools, the method and the level. And we can use n-dimensional affair-element

$$I = \begin{pmatrix} d, & h_1, & u_1 \\ & h_2, & u_2 \\ & \cdots & \cdots \\ & h_n, & u_n \end{pmatrix} = (d, H, U)$$

to describe the verb d which is expressed by characteristics h_1, h_2, $\cdots$, h_n and respective measure u_1, u_2, $\cdots$, u_n.

The relations and operations of matter-element and affair-element have been set up in refs. [1—10]. Thus we can describe various matters and affairs in the real world with formalized symbols; we can describe various strategies and ideas with the help of matter-element transformations, affair-element transformations and their operations.

1.1.2 Extensibility of matter-element. The key to solve contradictory problems is the study of properties about matter-elements, from which the matter-element theory is formed. In the course of solving contradictory problems, we must come out of the habitual domain, open up things involved in the problems and put forward creative methods. Refs. [3—5] studied extensibility of matter-element, including the divergent nature, the conjugate nature, the correlative nature, the implicative nature and the expansive nature. The above extensibility, which makes it possible to open up things from different view points, is the basis for both creative thinking and solving contradictory problems. Ref. [11] studied the implicative nature in detail, and then discusses the implication systems and their properties.

(1) The divergent nature of matter-elements

A matter has many characteristics, and one characteristic or one characteristic-element can be possessed by many matters, etc. All these properties are called the divergent nature. According to different divergent rules, we can get different divergent matter-element sets from a given matter-element.

Nature 1. A matter has many characteristics, called one matter many characteristics, written as

$$N_0 — | (N_0, c_0, v_0) — | \{R \mid R = (N_0, c, c(N_0)), c \in E(c)\},$$

which shows that matter N can have characteristics $c_1, c_2, \cdots, c_n$ besides c_0. The symbol "—|" means opening up, where $E(c)$ is the universal set of characteristics.

Nature 2. One characteristic can be possessed by many matters, called one characteristic many matters, written as

$$(N_0, c_0, v_0) — | \{R \mid R = (N, c_0, c_0(N)),\ N \in E(N)\},$$

where $E(N)$ is the universal set of matters.

Nature 3. One characteristic-element can be possessed by many matters, called one characteristic-element many matters, written as

$$(N_0, c_0, v_0) — | \{R \mid R = (N,\ c_0, v_0),\ N \in E(N)\},$$

$$\cdots\cdots.$$

(2) The conjugate nature of matter-elements

The study on the inner structure of matters helps us understand the transformations and relationship between different parts more clearly. System theory has given a kind of description on the inner structure of matters, which studies matters from the composition and the relationship between inside and outside of a system. The analysis on lots of matters has shown that the inner structure of matters can be studied from material nature, dynamic nature and opposite nature as well as system nature[5,12].

From the view point of material nature of matters, a matter can be divided into two parts: imaginary part and real part. It is saying that the real part is the base and the imaginary part is what we used. Every matter is the entity of the real part and the imaginary part. For example, the wall, the ceiling and the floor are the real part of a house while the space in the house is its imaginary part where we live. And the body of a product is its real part while the brand is its imaginary part. Imaginary part can also be classified into two subclasses: subjective imaginary part and objective imaginary parts. The imaginary part such as the space of a cup, that of a house and that of a gate are the objective imaginary parts. The imaginary part, of which we can be conscious, such as brand, fame and image are subjective imaginary parts. If we

denote the imaginary part of matter N by $\mathrm{im}N$ and the real part by $\mathrm{re}N$, then we have

$$N = \mathrm{im}N \otimes \mathrm{re}N.$$

Let $\mathrm{im}N$ and $\mathrm{re}N$ be new matters. Then we can describe the imaginary part and real part respectively by imaginary matter-element and real matter-element. For example,

$$\begin{bmatrix} \mathrm{im}N, & c_1, & v_1 \\ & c_2, & v_2 \\ & \cdots & \cdots \\ & c_n, & v_n \end{bmatrix}$$

is the imaginary matter-element of matter N.

Under certain circumstances, some imaginary matter-element and real matter-element can interchange with each other. This nature is called the conjugate nature between imaginary part and real part.

Similarly, a matter can be divided into two parts-soft part and hard part from the view point of system nature; latent part and apparent part from the view point of dynamic nature; negative part and positive part from the view point of opposite nature as well. We can describe the respective conjugate parts by matter-elements. The corresponding transformability is called respectively the conjugate nature between the soft and the hard, between the latent and the apparent and between the positive and the negative.

(3) The correlative nature of matter-element

Correlation means one of the following cases: (ⅰ) the dependency relationship of measure between two matters with respect to a certain characteristic; (ⅱ) the dependency relationship of measure between two different characteristics with respect to a certain matter; (ⅲ) the dependency relationship of measure between two matters of the same class with respect to a certain characteristic.

Due to the correlative nature, the measure change can bring about the change of correlative matters; the measure change of a matter or a cluster of matters with respect to a certain characteristic can lead to the measure change with respect to correlative characteristics. These kinds of change can be conducted in a correlative net of matter-elements. With correlative nature, we can solve the unknown problems and the feasibility problems[5]. Moreover, we must consider the change of correlative matter-elements in making matter-element transformation. It can be said that the correlative nature is the basis for studying the chain reaction of transformations. The method to solve unknown problems and feasibility problems, which make use of the correlative nature and matter-element transformation, is called the correlative net method.

The correlative nature of matter-element is the formalized representation of cause and effect[3,5]. The correlative net, consisting of correlative matter-elements and conduction transformations of matter-elements, describes the conductive reaction caused by the change of matters.

(4) The implicative nature of matter-element

References [3, 11] discuss the implication nature of matters and implication system.

A implies B means that "if A@, then B@", written as

$$A \Rightarrow B,$$

where @ stands for existence. The relation between A and B is called the implication relation, which can exist among matters, characteristics, measure, characteristic-elements and matter-elements. The elements B_1, B_2, $\cdots$, B_n and the implication relation among them constitute an implication system B.

(5) The expansive nature of matter-elements

The expansive nature of matter-elements describe the possibility of combination and decomposition for matter-elements, which has been given in refs. [3,5] by formalized methods.

The extensibility of affairs has been discussed in reference [10].

1.1.3 Matter-element transformations. With the introduction of the concept of matter-elements, transformations of matters, characteristics and measure can be viewed as extension theory's special operations. Consequently extension theory can describe the process containing both quantitative change and qualitative change. The extensibility of matter-element points out the possible way to solve problems, so the ideas and strategies can be described by matter-element transformations and their combination. Refs. [1—7] have given a comprehensive discussion on matter-element transformations.

The transformation which turns $R_0 = (N_0, c_0, v_0)$ into another matter-element $R = (N, c, v)$ or into several matter-elements $R_1 = (N_1, c_1, v_1), \cdots, R_n = (N_n, c_n, v_n)$, is called the transformation of R_0.

Replacement, decomposition, increasing or decreasing, and expansion or contraction are four basic transformations of matter-elements . Matter-element transformations possess four basic operations, namely, product, negation, and, and or [3,5]. The properties of matter-element transformation have been discussed in reference [5].

The transformation of a given matter-element can bring about the transformation of correlative matter-elements called conductive transformation. The conductive effect of conductive transformation should be considered in decision-making. Ref. [5] studied the vibration from conductive transformation. Ref. [6] discussed the rules for matter-element transformations. Refs. [12] and [14—18] discussed the philosophical value of extension theory.

1.2 Extension set

Set theory is a kind of mathematical method that describes the pattern recognition and classification about objectives. Objectives are complicated and always in change, so the mode for pattern recognition and classifications is not unique, but many and varied.

Cantor set describes the definiteness of matters while fuzzy set describes the fuzziness, and they both describe mainly the static property of matters. In order to describe the transformation, which turns one matter that does not possess property P into another matter that possesses property P, we must set up a new set which is the basis in solving contradictory problems.

1.2.1 The concept of extension set. Extension set is composed of two definitions. One can be regarded as the quantitative tool to describe quantitative change and qualitative change, and the other can describe qualitative change under certain circumstances.

Definition 1. Let U be the universe of discourse; K be a mapping from U to a real number field I. Then

$$\tilde{A} = \{(u, y) \mid u \in U, y = K(u)\}$$

is called an extension set of U, $y = K(u)$ the dependent function of $\tilde{A}$, $K(u)$ the dependent degree of u about $\tilde{A}$. And

$$A = \{u \mid u \in U, K(u) \geqslant 0\},$$
$$\bar{A} = \{u \mid u \in U, K(u) \leqslant 0\},$$
$$J_0 = \{u \mid u \in U, K(u) = 0\}$$

are called respectively the positive field, negative field and zero boundary.

Clearly, $u \in J_0$ implies $u \in A$ and $u \in \bar{A}$.

Three kinds of transformations of $\tilde{A}$ on U were stipulated in ref. [4], namely, the transformation T_u of elements, the transformation T_k of dependent function and the transformation T_U of the universe of discourse T_U.

Definition 2. Let $\tilde{A}$ be extension set on U, $T \in \{T_u, T_k, T_U\}$ be a transformation of $\tilde{A}$ such that $TU = U(T)$, $TK(u) = K'(u)$, $u \in U(T)$. Then

$$A_+(T) = \{u \mid u \in U(T), K(u) \leqslant 0, K'(Tu) \geqslant 0\},$$
$$A_-(T) = \{u \mid u \in U(T), K(u) \geqslant 0, K'(Tu) \leqslant 0\}$$

are called respectively positive extension field and negative extension field with respect to transformation T. In the case of $u \notin U$, we set $K(u) \leqslant 0$.

Classical set studies the definiteness of matters, fuzzy set studies the fuzziness of matters while extension set studies the transformability of matters. The essential difference among these is as follows:

(i) extension field describes the qualitative change in which a given matter that does not possess the property P can turn into another matter that possesses the property P.

(ii) The elements in zero boundary describe the critical point of qualitative change[5], which possesses the property P and does not possess the property P at the same time. For example, the man,

standing on the threshold with one foot inside the house and the other foot outside the house, belongs to the set of people both inside the house and outside the house. Extension set can describe both quantitative change and qualitative change. The change which does not bestride the zero boundary is quantitative change while the one which bestrides the zero boundary is qualitative change.

(ⅲ) If the element in extension set is matter-element, then the extension set is called extension matter-element set. Extension matter-element set combines quality and quantity together; it can describe quantitatively the relationship between the change of matter and the change of dependent degree with respect to property P.

The concept of extension set and its properties have been discussed in refs. [1—6] and [19].

1.2.2 Dependent function

Dependent functions, which express the dependent degree that a given matter possesses property P, were studied in refs. [1—6]. Computational method of dependent functions on real axis has been studied in ref. [1]. The concept of distance in real variable functions has been generalized. The distance on real axis between point x and a given real interval $X_0 = \langle a, b \rangle$ is defined as

$$\rho(x, X_0) = | x - (a + b)/2 | - (b - a)/2,$$

and the formulas of dependent function can be defined as

$$K(x) = \rho(x, X_0)/D(x, X_0, X),$$

where $D(x_0, X_0, X) = \begin{cases} \rho(x, X) - \rho(x, X_0) \\ -1 \end{cases}$. The types of dependent functions and their construction methods were studied in reference [5].

1.3 Extension logic

In the real world, "yes" and "no" can transform mutually, "non-compatibility" and "compatibility" can transform into each other too. Refs. [20—24] studied the rules for transformations, reasoning rules, set up a primary matter-element logic system, and points out that extension logic is a new kind of logic besides formal logic and dialectical logic. It is worth mentioning that extension logic consists of matter-element logic, affair logic and question logic.

Extension mathematics based on extension set was studied in refs. [25] and [26]. Extension mathematics will become the quantitative tool to solve contradictory problems.

2 Extension methods

Extension methods[3] are the special methods of extenics. They come from the further study of matter-element extensibility. Extension method has the following three basic methods:

(ⅰ) matter-element extension methods, including the method of divergent tree, that of conjugate pair, that of decomposition and composition chain, that of correlative net and that of implicative system;

(ⅱ) matter-element transformation methods, including basic transformation method, combination transformation method and transforming bridge method;

(ⅲ) appraisal method——appraisal method of dependent degree and rhombus thinking method which is useful in actual problems.

Extension methods have four characteristics:

(ⅰ) Extension methods are based on extensibility of matter-element. Matter-element is the logic cell of extensics; it has a lot of characteristics. These characteristics are bases in solving problems and of the extension method. By virtue of extensibility, we can analyze the various possibility of matter's change and then we can put forward solution to problems. All these used to be done before by only one's intuition.

(ⅱ) Matter-element model is basic model to solve contradictory problems. The concept of matter-element makes the starting point in solving contradictory problems change from mathematical models to matter-element models, which not only consider the quantitative relation or space forms but also considers matters, characteristics and their measure together. If we disregard the change of matters and characteristics, the matter-element model will degenerate into a mathematical model. Matter-element model is the

tool we use to solve contradictory problems in real life.

(iii) The way to solve contradictory problems is determined by rhombus thinking method. Rhombus thinking method describes man's thinking process in which divergent process is carried out before convergent process. The divergent process applies the extension method while the convergent process applies the appraisal method of dependent degree, which is based on extension set and dependent function.

Rhombus thinking method is the combination of divergent process and convergent process, in which qualitative analysis is carried out before quantitative analysis. Rhombus thinking method makes full use of the two theoretical pillars of extension theory, namely, matter-element theory and extension set theory.

Multistage rhombus thinking method can describe the process to solve contradictory problems by formalization method.

(iv) Matter-element transformation is the tool to solve contradictory problems. Rhombus thinking method provides the way to solve contradictory problems while matter-element transformations are basic tools to solve contradictory problems. There are four basic transformations of matter-element, from which various transformations can be constructed.

Matter-element transformations can result in the transformations of correlative matter-elements, so it is necessary to consider the conductive effect of matter-element transformations and their conduction methods.

3 Extension engineering methods and their application

3.1 Extensibility of information and extension information methods

References [31—34] studied the extensibility of information and extension information method, which shows that information can be represented by matter-elements $R = (N, c, v)$ and their combination. For example, R = (the White Swan Hotel, position, in Guangzhou) is used to describe the information "There is a hotel called the White Swan Hotel in Guangzhou". We can open up information from this information such as R_1 = (the White Swan Hotel, degree, 5 star), etc. As we know, extension methods of matter-element include divergent tree method, conjugate pair method, chain method of decomposition and combination, correlative net method and implication method. From a given information matter-element $R = (N, c, v)$, we can open up a set of matter-elements

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

which is a set of the extension information of the original information.

Extension information describes the various possibilities in creative thinking process while rhombus thinking method[5] describes the process of man's creative thinking. From the given information, we can open up a set of extension information by matter-element extension method, and then we can get rid of "garbage" information and find useful information by the appraisal method. We use the appraisal method of dependent degree in appraising matter-element, which has the following two characteristics: (i) A necessary premise is introduced. (ii) The appraisal method based on dependent functions, which have both positive and negative value, is used.

Extension diagnostic method on system fault was studied in ref. [35] by extension information method.

3.2 Formalized method on creative thinking

Creative thinking is a process that combines extension method and convergent method. Refs. [36—39] applied rhombus-thinking method to new products conception and technological innovation. In this process, we firstly set up the matter-element expression for the known information, and then we open up a set of matter-elements by matter-element extension method; finally we get the useful information by appraisal method of dependent degree. Ref. [6] studied the key steps in value engineering to find creative method by matter-element transformations, and ref. [36] discussed the rules and ways for "giving out ideas and working out methods", called the 3-4-3 method. Refs. [37—39] studied the method of new product conception staring from the functions of products and the known products.

3.3 Extension system method

Reference [40] studied contradictory problems in systems by matter-element theory, introduced con-

cepts of system matter-element and structural matter-element, and set up matter-element models in which the gap between existential states and expected states of a system matter-element is called system contradictory problem. It also developed set model and relation model for system contradictory problem, proposed some basic principles for extension system, and gave basic procedure to solve system contradictory problems.

3.4 Extension decision method

Decision-makers often meet all kinds of problems. In order to make decisions on contradictory problems, we have to study strategies and generating methods. Refs. [41, 42] studied extension decision method in solving contradictory problems. In extension decision method, using matter-element theory, we firstly get a series of strategies by transformations of goal matter-elements or condition matter-elements, and then we appraise these strategies comprehensively using extension set and dependent function. Finally through feedback process and adjustment, we find the decision strategies, which have the biggest dependent degree. In extension decision method, we often use transforming bridge method to solve opposite problems, i.e. contradictory problems between two different goals. In decision process, someone is good at using the strategy of "How the little David defeated the mighty Golliath?"; someone may lose the game owing to one false move; someone also grasps the key strategy but ignores its conductive actions to others, so that the imbalance of the overall situation appears. Ref. [43] set up some concepts such as strategy, key strategy, influence function and coordination problems by formalized method, discussed coordination problems of "grasping the vital part and giving consideration to the overall situation" as well.

In the fields of politics, economics and military, people always face various opposite problems and opposite systems. The transforming bridge method is a new kind of method in dealing with opposite problems ingeniously, which has the feature that each of the opposite sides goes his own way and is in his proper place. For example, it is well known that vehicles go along the left side of the road in Hongkong and go along the right side of the road in the Mainland China. If we directly combine these two traffic systems, whose traffic regulations are opposite, into a bigger traffic system, then the vehicles must come into collision. Hence, a special bridge has been set up in Huanggang, Shenzhen City. Through the bridge, the vehicles going left from Hongkong will naturally go along the right side of the road , while the vehicles going along the right side of the road from the mainland China will naturally go along the left side of the road. We use the concept of this bridge to describe the key part of solving opposite problems, called the transforming bridge[12].

Reference [44] studied the concepts , types, construction methods and application of transforming bridge. Transforming bridge method plays a particular role in solving contradictory problems. In order to carry out two opposite goals in the meantime or transform opposite systems into compatible system, it is necessary to set up transforming bridge. By transforming the bridge method, we can solve lots of opposite problems.

3.5 Application in economy and management

The application of extension theory in economy and management was discussed in refs. [11, 45, 49]. The static model and dynamic model for enterprises diagnosis were set up by implication system method in ref. [46], which is a special tool for enterprise decision, and three ways to develop strategy set are also proposed . The concepts of imaginary matter-element and real matter-element were given in ref. [47], the conjugate characteristics and conjugate matter-element were proposed and the application of imaginary matter-element in marketing was studied as well.

Dynamic models in ref. [48] illustrated the cause of producing market trap, and the business countermeasure against market trap was set up by matter-element transformation methods. The enterprise decision of oligopoly was analyzed by matter-element transformations in ref. [49], which showed that matter-element transformations is an available tool to develop strategy set for enterprise decision of oligopoly. The application of extension theory in marketing was discussed in the earlier study of the national natural foundation project of research on extension marking method (No.79870107). The research work in recogni-

tion and appraisal of extension theory was shown in reference [8].

3.6 Application in control

The intelligent control was studied by extension theory in refs. [50—53], and the basic concepts, structure and principles of extension control were proposed. The control process of an extension control system consists of the following parts: data base, knowledge base, pattern recognition of characteristics, calculation of dependent degree on characteristic states, pattern recognition of measure, reasoning mechanism, control strategies.

Extension expert system was studied in ref. [52]. It is shown in ref. [53] that extension expert system has four parts: extension knowledge base, data base, organization part and appraisal part. In an extension expert system, we firstly express knowledge by extension theory, and then set up extension knowledge base, and finally establish decision support system and extension appraisal mechanism.

3.7 Application in artificial intelligence

The primary computer research on non-compatible problems was discussed in refs. [54—59], and the research branch of extension theory on artificial intelligent was proposed. The concept of extension language was given in ref. [56]. It is shown that extensibility is an important characteristic of natural language, which is embodied in the following aspects:

(1) The logical intension of some sentences and that of some words in natural language varies with time.

(2) Natural language contains lots of extension information.

(3) Natural language has critical properties.

However, computer can understand only formal language. In order to make computer do more work instead of man, it is necessary to quantify part of the natural language properly and set up a new quantitative model, extension language model, for the natural language. In addition, the research on extension algorithm, which possesses intelligent characteristics, is an important research branch of Extenics in the application of Artificial Intelligence, and it is also a premise of computerization in solving contradictory problems.

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