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A new method for fish-disease diagnostic problem solving based on parsimonious covering theory and fuzzy inference model

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Abstract: There are three kinds of uncertainty in the process of fish-disease diagnosis, such as randomicity, fuzzy and imperfection, which affect the veracity of fish-disease diagnostic conclusion. So, it is important to construct a fish-disease diagnostic model to effectively deal with these uncertainty knowledge's representation and reasoning. In this paper, the well-developed parsimonious covering theory capable of handling randomicity knowledge is extended. A fuzzy inference model capable of handling fuzzy knowledge is proposed, and the corresponding algorithms based the sequence of obtaining manifestations are provided to express imperfection knowledge. In the last, the model is proved to be effective and practicality through a set of fish-disease diagnostic cases.

Key-Words: Fuzzy set theory, Parsimonious covering theory, Fish-disease diagnosis

1 Introduction

There are three primary kinds of uncertainty in the process of fish-disease diagnosing, which are randomicity, fuzzy and imperfection. Randomicity is a kind of uncertainty and is usually calculated by probability theory. It can't provide completely definite conclusion because the causal relationship between fish-disease and manifestation is ambiguity. Fuzzy usually represented with fuzzy set theory is another kind of uncertainty that is induced by the fact that fish-disease diagnostician and technologist haven't a clear perspective of the degrees of observed manifestation and the concept of domain diagnostic knowledge. Imperfection is the third kind of uncertainty which is induced by the fact diagnostic information are not sufficient because of the limitation of people's knowledge and impersonality condition. Because of three kinds of uncertainty being in existence at the same time, either probability theory or fuzzy inference model can't completely settle out fish-disease diagnostic problem. So, it is important to construct a fish-disease diagnostic model that can effectively deal with these uncertainty knowledge's representation and reasoning.

PCT (Parsimonious Covering Theory) based on probability model, one of the well-developed inference models for diagnostic problem solving proposed by Peng and Reggia [1,2], primarily describes and formalizes general diagnostic problem in a reasonable and strict mathematics manner. In their work, the most salient contribution is the development of a probability criterion for describing the plausibility of a diagnosis hypothesis. As stated in Ref. [4], in the real world of medical diagnosis, the manifestations may not be able to be properly represented as a binary quantity, instead they may be observed with degrees. It is difficult to represent degrees of manifestations by the probability theory, and fortunately the fuzzy set theory provides a formal way to deal with this problem.

In this paper, the well-developed parsimonious covering theory based probability model is extended. A alternative fuzzy inference model capable of handling fuzzy knowledge for fish-disease diagnostic problem solving is proposed, and the corresponding algorithms based the sequence of obtaining diagnostic information are provided. This model can deal with degrees of manifestations simultaneously and sequences of obtaining diagnostic information.

Firstly, PCT and its probability model are introduced into fish-disease diagnosis domain. Secondly, the best probability criterion is determined on through analyzing fish-disease's characteristic, then the plausible function is calculated and the best solution is founded by thoroughly enumerate strategy and the biggest probability criterion. Thirdly, the limitation of the probability model of PCT solving fish-disease diagnosis is pointed out, in another word,

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it is difficult to represent the degrees of manifestations. So that, fuzzy set theory is introduced to represent degrees of manifestations and the diagnostic problem is newly defined. Finally, responding algorithm is proposed to deal with the imperfection of diagnostic information.

PCT (Parsimonious Covering Theory) based on probability model is extended in such a way that it is integrated with fuzzy set theory and corresponding sequence algorithm in this paper. The new model is applied into fish-disease diagnosis domain to deal with three-uncertainty knowledge's representation and reasoning. In the last, the model is proved to be effective and practical through a set of fish-disease diagnostic cases.

2 The fish-disease diagnostic model based on parsimonious covering theory

Parsimonious covering theory (PCT) is an attempt to formalize diagnostic reasoning, with the advantage that domain knowledge and general diagnostic problem solving methodology are clearly separated from each other. Briefly, the basic version of PCT defines the domain specific knowledge as a set of disorders (causes), a set of manifestations (effects), and a causal relation between disorders and manifestations. The causal relation associates each disorder with the manifestations it may cause. If one or more of these manifestations are actually present in a diagnostic case, then the disorder may be used to 'explain' those manifestations. A particular diagnostic problem is defined by a set of manifestations are actually observed in the patient, and the solution to that problem consists of sets of disorders where each set explains all the manifestations present.

In a particular diagnostic case, the process of diagnostic problem solving can be divided into two phases: Firstly, to find all probable disease sets that explain all observed manifestations and to define the scope of solution for diagnostic problems; Secondly, to calculate plausible function' value of these disease sets then to adopt the biggest plausible criteria and thoroughly enumerating strategy to find the best disease set.

2.1 Parsimonious covering theory

PCT uses two finite sets to define the scope of diagnostic problems. They are the set *D*, representing all possible disorders d_i that can occur, and the set *M*, representing all possible manifestations m_j that may occur when one ore more disorders are present. The relation *C*, from *D* to *M*, associates each individual disorder with its manifestations. An association $< d_i, m_j >$ in *C* means that d_i may directly cause m_j. To complete the problem formulation we need a particular diagnostic case. We use M^+, a subset of *M*, to denote the set of observations, which are manifestations present in a particular diagnostic case.

Definition 1. A diagnostic problem P is defined as a quadtuple $< D, M, C, M^+ >$, where:

D is a finite, non-empty set of elements, called disorders; and *M* is a finite, non-empty set of elements, called manifestations;

C is a binary relation between disorders and manifestations, called causation; it represents with a matrix form. A nonzero element c_{ij} means the probability that d_i may directly cause m_j;

M^+ is a subset of *M*, and it identifies all observed manifestations.

Definition 2. The set $D_I \subseteq D$ is the cover of $M_J \subseteq M$ if $M_J \subseteq Effect(D_I)$

Definition 3. A set $D_I^* \subseteq D$ is an explanation of M^+ for a diagnostic problem if *D* covers M^+, and satisfies a given parsimony criterion: simple, minimal, irredundant, and relevant criterion.

Definition 4. The solution of a diagnostic problem P is the set of all explanations of M^+ and it must satisfy a given parsimony criterion.

The abductive inference model is based upon the notion of parsimoniously covering a set of observed manifestations, M^+. The premise of the parsimonious covering theory is that a diagnosis hypothesis must be a cover of M^+ in order to account for the presence of all manifestations in M^+. On the other hand, not all covers of M^+ are equally plausible as the hypotheses for a given problem. It must be satisfy a given parsimony criterion: simple, minimal, irredundant and relevant criterion.

2.2 Decision about parsimony criterion in fish-disease diagnostic model

The key to solve disease diagnostic problem is to select a preferable parsimony criterion combined with diagnostic practice. In practice, if the diagnosis objective is different, parsimony criterion is too different.

(1) If the restriction of diagnostic object is single disorder, a cover D_I of M^+ is an explanation if it contains only a single disorder, a single disorder

principle should be adopted.

(2) If diagnostic object is a many-disorder system, parsimony criterion is adopted on the characteristic of disorder occurrence: relevancy, a cover D_I of M^+ is an explanation if it only contains the disorders that causally associate with at least one of the manifestations in M^+; irredundancy, a cover D_I of M^+ is an explanation if it has no proper subsets which also cover M^+ or, in other words, removing any disorder from D_I results in a noncover of M^+; minimality , a cover D_I of M^+ is an explanation if it has the minimal cardinality among all covers of M^+, i.e. it contains the smallest possible number of disorders needed to cover M^+.

So, we must firstly analyze the characteristic of fish-disease occurrence, it is summed as follows:

(1) The relationship between fish-disease and fish-disease is various: Two diseases may repel one another, and two diseases may be interrelated. If the relationship of two fish-diseases is interrelated, one disease may be occur directly, indirectly or along with another disease.

(2) The cause of one fish-disease is different in different environment: Many factors, such as intrinsic body, extrinsic environment and man-made management, will result in fish-disease. In the condition of modern intensive breeding, these factors are more easier to result in fish-diseases occurrence more than before.

(3) The diffusion of fish-diseases is various and interrelated: Any original fish-disease is likely to arise other fish-diseases in many potential ways. Any fish-disease likely arises another disease and is likely aroused by another disease too.

In diagnostic practice, two status, many-disease occurrence and simple disease occurrence, are in existence, so irredundancy criterion is adopted to define the scope of diagnostic solution.

2.3 The limitation of PCT's probability model

If the set of observed manifestations, M^+, is known, plausible function of these solution, disease sets which can explain M^+, can be found by probability theory, the best solution can be calculated by thoroughly enumerating strategy and the biggest plausible criterion. Plausible function $L(D_I, M^+)$ represents as follow：

$$L(D_I, M^+) = \prod_{m_j \in M^+} (1 - \prod_{d_i \in D_I} (1 - c_{ij})) \prod_{d_i \in D_i} \frac{p_i}{1 - p_i}$$

The limitation of PCT's probability model in the process of diagnosing fish-disease is summed as follow:

(1) The probability of d_i, $p(d_i)$, is supposed to be a known numeral in diagnostic model, in fact, the value of $p(d_i)$ is affected by many factors; it transforms along with factor's variation.

(2) Degrees of cause-and-effect relation, c_{ij}, is supposed to be known in diagnostic model, in fact, the value of c_{ij} is different if the diagnostic expert is different, so it need to statutes.

So, fish-disease diagnostic knowledge must be pretreated before the diagnostic model is applied into fish-disease diagnostic domain.

2.4 Pretreatments with fish-disease knowledge

Because fish-disease diagnostic system is complex, the factors that arise disease are different, but also the knowledge that experts hold is different because their diagnostic experience and the cognition degree of fish disease is different, so the diagnostic knowledge come from different channels constantly differs. It is necessary to foreclose this fish-disease knowledge in some statistic methods before it is introduced into PCT's probability model.

2.4.1 Decision about the scope of fish-disease

In this paper, fresh water fish-diseases occur in Tianjin is illustrated as examples. Some constantly occurring fish-diseases are summed up according to data provided by Tianjin aquatic company, and the occurring frequency is classified into four levels: 1) frequently; 2) often; 3) infrequently; 4) nonoccurrence. We defined the scope of fish-disease by which occurring frequency is bigger than 0.2.

2.4.2 Decision about the foresight probability of fish-disease $p(d_i)$

We consider that some factors are interrelated with fish-disease by analyzing a lot of investigation data; they are fish-kind, fish-age, occurring season, occurring area and pool-depth. The foresight probability can be decided by firstly confirming these environmental factors.

1. The first factor is fish-kind: If fish-kind is different, kinds of occurring fish-disease are too different. For example, some disease occurs in carp would not occurs in silver carp. We classify fish-kind into six kinds, such as grass carp, silver carp, variegated carp, carp, crucian carp and so on. Variable k_i represents the corresponding kind;

function $cause(k_i) = \{d_j \mid j = 1,2,...,n\}$ represents disease sets when fish-kind is k_i.

2. The second factor is fish-age: If fish-age is different, kinds of occurring fish-disease are too different. For example, some disease occurs in parent fish would not occur in fish-breed. We classify fish-age into four phases, such as fry, fish-breed, grow-up fish, parent fish and so on. Variable a_i represents the corresponding age, function $cause(a_i) = \{d_j \mid j = 1,2,...,n\}$ represents disease sets when fish-age is s_i.

3. The third factor is season: If season is different, kinds of occurring fish-disease are too different. For example, some disease occurs in spring would not occur in summer. We classify occurring season into: spring, summer, autumn and winter four phrases, variable s_i represents the corresponding season, function $cause(s_i) = \{d_j \mid j = 1,2,...,n\}$ represents disease sets when occurring season is s_i.

4. The fourth factor is area: If area is different, kinds of occurring fish-disease are too different. For example, some diseases occur in certain area will not occur in other area. Variable pl_i represents corresponding area name, function $cause(pl_i) = \{d_j \mid j = 1,2,...,n\}$ represents disease sets when occurring area is of pl_i.

5. The probability of fish-disease, p_i, can be calculated by algorithm as follow:

F_1^+: A subset of F^+, it defines factors, such as fish-kind (k_i), fish-age (a_i), occurring season (s_i), occurring area (p_i) and so on;

D_I: Disease sets that can explain the observed manifestations;

The beginning state is that $F_1^+ = \Phi, D_I = D$; the terminating condition is that $F_1^+ = F^+$, $F^+ = \{k_i, a_i, s_i, p_i\}$. Diagnostic algorithm can be described as follow:

(1) input k_i from F^+;

(2) $F_1^+ = F_1^+ \cup k_i$;

(3) $D_I = D_I \cap cause(k_i)$;

(4) $F_1^+ = F_1^+ \cup a_i$;

(5) $D_I = D_I \cap cause(a_i)$;

(6) $F_1^+ = F_1^+ \cup s_i$;

(7) $D_I = D_I \cap cause(s_i)$;

(8) $F_1^+ = F_1^+ \cup p_i$;

(9) $D_I = D_I \cap cause(p_i)$;

(10) extract D_I and the number of disease in D_I ;

(11) the probability of each disease should be $p_i = 1/I$。

2.4.3 Decision about degrees of cause-and-effect relationship c_{ij}

In the process of diagnosing fish-disease, degrees of cause-and-effect relation should keep to principles as follow:

1) Because each disease can represent many manifestations, they are classified three levels: necessarily appearing, constantly appearing and occasionally appearing, the level of manifestation should be confirmed at first.

2) Necessarily appearing manifestation plays a decisive role in disease diagnosing, so the value of c_{ij} is defined as 1.0;

3) Constantly appearing manifestation frequently appears in process of certain fish-disease occurring, which can affect the reliability of diagnostic solution, so the value of c_{ij} is defined between 0.3 and 0.9;

4) The specialty of occasionally appearing manifestation is probably occurring; the value of c_{ij} should be between 0 and 0.2.

The equation is $\overline{c_{ij}} = \frac{1}{n}\sum_1^n c_{ij}$ by analyzing questionnaires of 24 experts in Tianjin.

In the process of diagnosing fish-disease, there are three uncertainties: probability, fuzzy and imperfection. The model describing as up can deal with probability, but degrees of manifestation and the imperfection and sequence of diagnostic information are not taken into account. So we must improve on this model.

3 Diagnosis model based on fuzzy theory and diagnosis algorithm

3.1 Diagnosis model based on fuzzy theory

If degrees of observed manifestation are introduced into parsimonious set covering, diagnosis problem is redefined as follow:

Definition 5 "manifestation-disease" diagnosis problem is defined as a quadtuple (D, M, R, M^+), where:

$M^+ = \{m_1, m_2, ..., m_k\}$ is a fuzzy subset of

M，and it identifies the observed manifestations. To each $m_j \in M^+$, $\mu(m_j) \in [0,1]$ is the observed degree of m_j.

In accordance with the diagnostic problem definition written as up, plausible function of diagnostic solution is defined as follow:

Definition 6 $L(D_I, M^+)$ **expresses the degree that** D_I **explains the set of manifestations** M^+**, and the equation is tenable:**

$$L\ (D_I, M^+) = \prod_{m_j \in M^+} \mu(m_j)(1 - \prod_{d_i \in D_I}(1 - c_{ij})) \prod_{d_i \in D_I} \frac{p_i}{1 - p_i}$$

The plausible function is in keeping with the fact: $\mu(m_j)$ gradually increases along with degrees of manifestation augments. If the possibility that one manifestation is observed is big, the possibility that one disease can explain the manifestation is comparatively big.

3.2 The selection on fuzzy degree of manifestation

In diagnosing practice, ordinary fishery technicians and fisher folks are accustomed to adopt fuzzy language to describe degrees of manifestation. Each manifestation description is classified five levels, they are “absolutely same, close, relatively close, not same, different”, then corresponding fuzzy value is present to make user easy to describe the observed manifestation.

3.3 The algorithm of diagnosis model

The process of fish-disease diagnosis is to find disease sets that can explain a set of observed manifestations through correlative diagnostic knowledge. It behaves as a repetitious process: preparatory examining- first diagnosis- examining again- diagnose again----make a definite diagnostic solution. In the process, old hypothesis is excluded and new hypothesis is brought up. The circulation repeats again and again until the best solution is brought up. On the basis of analyzing diagnostic process, the corresponding algorithm is present. The basic idea of the algorithm is that the original manifestation set is provided; a trial disease hypothesis can be brought up to explain these manifestations, then current hypothesis can instruct us to find more information for the best solution.

Before introduce the algorithm, we must firstly make some definitions:

M_1^+ is a subset of M^+, and it identifies the set of observed manifestations;

$D_I, cause(M_1^+)$, it identifies disease sets that can explain observed manifestations;

S is trial solution sets of observed manifestations;

“×” represents Descartes accumulation, and the original state is $M_1^+ = \Phi, D_1 = \Phi, S = D$, the terminate condition is $M_1^+ = M^+$, in another word, all observed manifestations have been inputted into the model.

The algorithm of diagnosis can be described as follow:

(1) Input m_j from M^+ ;

(2) $M_1^+ = M_1^+ \cup m_j$;

(3) $D_I = D_I \cup cause(m_j)$;

(4) $S'' = S' - S, S' = S$, $S = S \cap cause(m_j)$

(5) IF $S = \Phi$ THEN ;

{ $S_1 = S' \times cause(m_j)$

IF $\left(effect(s'') \cup effect(\{d_i \mid d_i \in cause(m_j)\})\right)$ is the smallest covering set of M_1^+

THEN $S_2 = \{d_i\} \times S''$

ELSE $S_2 = \Phi$

$S = S_1 \cup S_2$ }

(6) IF $M_1^+ = M^+$ THEN end

ELSE go to (1)

After all probable diagnostic solutions have been found, the plausible function of S can be calculated and the best solution can be found by thoroughly enumerating strategy and the biggest plausible criterion.

4 Test results

Two sample studies are served for testing the developed fuzzy inference model, and the description of each example and some of the test results are given below.

Two example is from Jingwu aquatic product breeding factory in Tianjin. After four factors such as k_i =grass carp, a_i =fish-seed, s_i =summer and pl_i =Jinghai are confirmed，disease sets that can explain these factors can be calculated, it is D_I =22, in another word, the probability of each fish-disease is p_i =1/22。Which contains 22 disorders and 44 manifestations. The cause-and-effect relationship between disease and manifestations is shown in matrix. More than 20 test cases have been carried out for this example. Only two test cases are illustrated below for saving space.

Table 1 d_i **and** $effect(d_i)$

	$fect(d_i)$		$effect(d_i)$
	1 m_{46}	2	4
	0 m_{30} m_{33}	3	2 m_{11} m_{18}
	4 m_{15} m_{43}	4	4 m_{15} m_{19} m_{25} m_{32} m_{34}
	5	5	7 m_{23} m_{29}
	2	6	9 m_{27}
	5 m_{33}	7	5 m_{16} m_{17} m_{41} m_{42}
	7 m_{38}	8	4 m_{18} m_{19} m_{28} m_{31} m_{41}
	3	9	1
	0 m_{33}	0	4 m_{15} m_{16} m_{21} m_{28} m_{30} m_{41} m_{44}
0	1 m_{03} m_{20} m_{35}	1	8
1	1 m_{15} m_{18} m_{19} 6 m_{28} m_{30}	2	4 m_{19} m_{22} m_{25} m_{36} m_{39} m_{40}

The degree of cause-and-effect, R, is expressed by matrix:

$R =$

	m_{01}	m_{02}	m_{03}	m_{04}	m_{05}	m_{06}	m_{07}	m_{08}	m_{09}	m_{10}	m_{11}	...	m_{45}	m_{46}
d_{01}											0.2			0.8
d_{02}										0.2				
d_{03}														
d_{04}													1	
d_{05}														
d_{06}					0.8									
d_{07}														
d_{08}														
d_{09}										0.2				
d_{10}	0.2		0.4											
d_{11}														
d_{12}											0.8			
d_{13}		1									0.3			
d_{14}				1										
d_{15}							1							
d_{16}									1					
...														
d_{21}								1						
d_{22}				0.6										

4.1 test case 1

If $M^{+} = (m_{15}, m_{16}, m_{42})$, degrees of manifestation separately is: $\mu(m_{15}) = 0.8$, $\mu(m_{16}) = 0.5$, $\mu(m_{42}) = 0.3$, the transformation of disease set in the process of diagnosis is described as Table 2.

Table 2 the diagnosis result of algorithm for test case 1

Manifestations	Original state	m_{15}	m_{16}	m_{42}
M_1^{+}	Φ	$\{m_{15}\}$	$\{m_{15}, m_{16}\}$	$\{m_{15}, m_{16}, m_{42}\}$
D_1	Φ	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$
S'	Φ	D	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$	$\{d_{17}, d_{20}\}$
S''	Φ	Φ	$\{d_1, d_{02}, d_{04}, \ldots, d_{19}, d_{21}, d_{22}\}$	$\{d_{03}, d_{11}, d_{14}\}$
S	D	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$	$\{d_{17}, d_{20}\}$	$\{d_{17}\}$

1) When manifestations observed is $\{m_{15}\}$, diagnostic model will diagnose that disease set is $\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$, user can be instructed to choose other manifestation to obtain the diagnostic solution according to known disease set.

2) When manifestations observed is $\{m_{15}, m_{16}\}$, diagnosis system will diagnose that disease set is reduced to be $\{d_{17}, d_{20}\}$, user can be instructed to choose other manifestation explained by $\{d_{17}, d_{20}\}$.

3) In the case of manifestation set observed being $\{m_{15}, m_{16}, m_{42}\}$, disease set is $\{d_{17}\}$.

Finally, the last answer $S = \{d_{17}\}$, in another word, when $M^{+} = (m_{15}, m_{16}, m_{42})$, the result of diagnosis is enteritis. It is obvious that the process of fish-disease diagnosis is a process of seeking more perfection answer ‘step by step’ based on “hypothesis -test” circulation. In the process of diagnosis, part known manifestation is imported, corresponding disease set will be obtained through diagnosis system. The method can instruct user to collect more manifestation expressed by disease set， the scope of disease will gradually reduced to perfect diagnosis result.

4.2 test case 2

$M^{+} = (m_{15}, m_{16}, m_{34})$,the degree of manifestation separately is: $\mu(m_{15}) = 0.8$, $\mu(m_{16}) = 0.5$, $\mu(m_{34}) = 0.3$, disease set transformation in the process of diagnosis can be expressed as Table 3.

Table 3 the diagnosis result of algorithm for test case 2

症状	初始	m_{15}	m_{16}	m_{34}
M_1^{+}	Φ	$\{m_{15}\}$	$\{m_{15}, m_{16}\}$	$\{m_{15}, m_{16}, m_{34}\}$
D_1	Φ	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$
S'	Φ	D	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$	$\{d_{17}, d_{20}\}$
S''	Φ	Φ	$\{d_1, d_{02}, d_{04}, \ldots, d_{19}, d_{21}, d_{22}\}$	$\{d_{03}, d_{11}, d_{14}\}$
S	D	$\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$	$\{d_{17}, d_{20}\}$	$\{d_{17}, d_{20}\} \times \{d_{14}\}$

1) When manifestations observed is $\{m_{15}\}$, disease set obtained by diagnosis system is $\{d_{03}, d_{11}, d_{14}, d_{17}, d_{20}\}$, user can be instructed to choose other manifestation to obtain the diagnosis result according to known disease set。

2) When manifestations observed is $\{m_{15}, m_{16}\}$,

disease set is reduced to be $\{d_{17}, d_{20}\}$。

3) When manifestations observed is $\{m_{15}, m_{16}, m_{42}\}$, disease set is $\{d_{14}, d_{17}\}, \{d_{14}, d_{20}\}$。We can alternatively choose the more perfect result by means of calculating plausibility function .

$$\frac{L(\{d_{14}, d_{20}\})}{L(\{d_{14}, d_{17}\}) + L(\{d_{14}, d_{20}\})} = \frac{L_1(\{d_{14}, d_{20}\})L_2(\{d_{14}, d_{20}\})}{L_1(d_{14}, d_{17})L_2(d_{14}, d_{17}) + L_1(d_{14}, d_{20})L_2(d_{14}, d_{20})} = 0.224$$

$$\frac{L(\{d_{14}, d_{17}\})}{L(\{d_{14}, d_{17}\}) + L(\{d_{14}, d_{20}\})} = \frac{L_1(\{d_{14}, d_{17}\})L_2(\{d_{14}, d_{17}\})}{L_1(d_{14}, d_{17})L_2(d_{14}, d_{17}) + L_1(d_{14}, d_{20})L_2(d_{14}, d_{20})} = 0.776$$

Table 4 **the final diagnosis result of algorithm**

Diagnosis result	Disease set	Probability
solution 1	$\{d_{14}, d_{17}\}$	77.6%
solution 2	$\{d_{14}, d_{20}\}$	22.4%

It is obvious that the model can work out the result in the case of sickliness subsequent. It is the advantage of diagnosis model based parsimonious set covering theory.

5 Conclusion

(1) Because of three kinds of uncertainty, such as randomicity, fuzzy and imperfection, being in existence in the process of fish-disease diagnosis, the degree of manifestations is sufficiently taken into account, a new method for fish-disease diagnostic problem solving based on parsimonious covering theory and fuzzy inference model is constructed in this paper. According to the sequence of diagnosis process, a 'step by step' seeking answer algorithm based on "hypothesis -test" circulation is proposed.

(2) The diagnosis model proposed in this paper is an efficient attempt to solve the fish-disease diagnosis problem, and realizes the integration probability inference with fuzzy set theory. Fish-disease can be diagnosed more reliably and practically by means of this model.

(3) The advantage of parsimonious covering model based on fuzzy set theory is analyzed through a great quantity cases. It not only can prompt user to collect more diagnostic information, but also can provide more perfect diagnostic outcome accord with the specialty of fish-disease.

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