A Fuzzy Method for Medical Diagnosis of Headache

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**SUMMARY** In this note we propose a fuzzy diagnosis of headache. The method is based on the relations between symptoms and diseases. For this purpose, we suggest a new diagnosis measure using the occurrence information of patient's symptoms and develop an improved interview chart with fuzzy degrees assigned according to the relation among symptoms and three labels of headache. The proposed method is illustrated by two examples.

**key words:** fuzzy measure, interview chart, fuzzy differential diagnosis

1. Introduction

Headache is one of the most common reasons for neurological consultation and has many causes and symptoms. There are two categories of headache: primary and secondary headache. Primary headache is not associated with other diseases. Examples of primary headache are migraine, tension, and cluster headache. Secondary headache is caused by associated diseases.

In this article we propose a medical diagnostic method of primary headache. First, we introduce a relation between symptoms and diseases, and develop an interview chart with assigned fuzzy degrees based on the relation among symptoms and three types (migraine, tension, and cluster) of headache. The interview chart is an improved version of our previous study [5]. Second, we propose a new measure for medical diagnosis using the occurrence information of symptoms for patient's diseases. At the end the performance of the interview chart and the measure is illustrated via two case studies.

2. Preliminaries

The fuzzy set framework has been utilized in several different approaches to model the diagnostic process [1], [9]–[12]. Sanchez [8] represented the physician's medical knowledge as a fuzzy relation between symptoms and disease, which was elaborated by Adlassnig [1].

As a generalization of fuzzy set, an intuitionistic fuzzy set (IFS) has been introduced by Atanassov [3]. However, there has recently sparked a debate over the use of the name 'intuitionistic'. Debois et al. [4] pointed out a terminological clash between Atanassov's 'intuitionistic fuzzy sets' and what is currently understood as intuitionistic logic, and argued that the name 'intuitionistic fuzzy sets' for Atanassov theory is unsuitable and misleading. Therefore we don’t use the name 'intuitionistic' except for the sense of Atanassov in this study.

For a fixed set $E$, an IFS $A$ in the sense of Atanassov is defined as follows:

$$A = \{x, \mu_A(x), \nu_A(x) \mid x \in E\},$$

where the functions $\mu_A: E \to [0, 1]$ and $\nu_A: E \to [0, 1]$ define the degree of membership and the degree of non-membership of the element $x \in E$ to the set $A$, respectively. For every $x \in E$,

$$0 \leq \mu_A(x) + \nu_A(x) \leq 1.$$ 

The amount $\pi_A(x) = 1 - (\mu_A(x) + \nu_A(x))$ is called the hesitation part, which may cater to membership value, non-membership value or both. This will be adapted to define a new medical diagnosis measure.

Let $S = \{S_1, \ldots, S_m\}$, $D = \{D_1, \ldots, D_n\}$, and $P = \{P_1, \ldots, P_q\}$ denote the sets of symptoms, diseases, and patients, respectively. According to Sanchez [8] approach for medical diagnosis, two fuzzy relations (FR) $Q$ and $R$ are defined as follows:

$$Q = \{(p, s), \mu_Q(p, s), \nu_Q(p, s) \mid (p, s) \in P \times S\},$$

$$R = \{(s, d), \mu_R(s, d), \nu_R(s, d) \mid (s, d) \in S \times D\},$$

where $\mu_Q(p, s)$ and $\nu_Q(p, s)$ indicate the degrees for patient's symptoms, i.e. $\mu_Q(p, s)$ indicates the degree to which the symptom $s$ appears in patient $p$, and $\nu_Q(p, s)$ indicates the degree to which the symptom $s$ does not appear in patient $p$. Similarly, $\mu_R(s, d)$ and $\nu_R(s, d)$ denote the set $S \times D$. The composition $T$ of $R$ and $Q$ ($T = R \circ Q$) for diagnosis of disease describes the state...
of patients in terms of disease as a FR from $P$ to $D$ given by
the membership and non-membership functions
\[
\mu_{T}(p_i, d) = \max \{ \min [\mu_{Q}(p_i, s), \mu_{R}(s, d)] \},
\]
\[
\nu_{T}(p_i, d) = \min \{ \max [\nu_{Q}(p_i, s), \nu_{R}(s, d)] \}
\]
for all $p_i$ $\in$ $P$ and $d$ $\in$ $D$.

3. Interview Chart

In diagnosis of headache, initial information (so-called symptoms) of the patient is collected by patient’s medical history and interview. Therefore, screening method using questionnaire is helpful in diagnosis of headache and interview chart is a leading part. We developed an interview chart for preliminary diagnosis of headache in our earlier work [2], where the qualitative data from the interview chart were obtained and then quantified by dual scaling. However, the method has some problems such as loss of information and insufficient use of physician’s knowledge.

In this study, we develop an improved interview chart, an extended version of the interview chart developed in our previous study [5], based on physician’s knowledge. In the improved chart, we reform the fuzzy degrees and add some composite symptoms. Composite symptom is a meaningful item for diagnosis of headache.

The improved chart consists of 22, 17, and 14 items (symptoms) for the three types (migraine, tension, and cluster) of headache, respectively. Each item has confirmability degrees with the relation among symptoms and three types of headache, and the chart is investigated by 5 physicians. In the chart for migraine, two items (item M21 and M22) display composite symptoms. For example, if a patient simultaneously has symptoms M5, M8, and M15, he/she has a composite symptom and it is displayed in the item M22. Likewise, the chart for tension and cluster headache has 2 items and 1 item with composite symptoms, respectively. We can estimate labels of headache of patients using the information obtained from the chart.

4. A Medical Diagnosis Measure

We in general determine the diagnostic labels of patient $p$ for any disease $d$ such that both inequalities $0.5 < \max [\mu_{T}(p, d)]$ and $\max [\nu_{T}(p, d)] < 0.5$ are satisfied [6]. However, $\mu_{T}(p, d)$ and $\nu_{T}(p, d)$ do not include the information about the occurrence frequency of symptoms for patient’s diseases. This information is an important factor in diagnosis of headache, while the information is disregarded in many researches for medical diagnosis [1], [2], [7]. In particular, it could play a significant role in diagnosis when many types of headache are presented in patients. If patients have more than 2 types of headache, therefore, we suggest the following improved measure using the occurrence information for medical diagnosis of headache:

\[
\nu_{T}(p, d) = \nu_{T}(p, d) - \pi_{T}(p, d) * f,
\]

where $\pi_{T}(p, d)$ is $1 - [\mu_{T}(p, d) + \nu_{T}(p, d)]$ and $f$ is the occurrence proportion of symptoms for patient’s diseases. For example, if a patient simultaneously has 3 types of headache and symptoms for each type occur 4, 2 and 14 times respectively, $f$ for 3 types is 0.2, 0.1 and 0.7 respectively.

This improved measure is a more significant indicator using occurrence information, and fuzzy relation is obviously retained. Thus we can determine the diagnostic labels such that both inequalities $0.5 < \max [\mu_{T}(p, d)]$ and $\max [\nu_{T}(p, d)] < 0.5$ are satisfied.

5. Case Examples

In this section, we present two case examples for diagnosis using the degree for patient’s symptoms $<\mu_{Q}(p, s), \nu_{Q}(p, s)>$ assigned by a physician, and confirmability degree $<\mu_{R}(s, d), \nu_{R}(s, d)>$ indicated in the interview chart.

(Example 1) Let us consider patient $P_1$. $P_1$’s symptoms are (M3, M5, M8, M12, M15, M18) of migraine. $P_1$ simultaneously has symptoms M5, M8, and M15, therefore the symptoms of $P_1$ are represented in (M3, M12, M18, M22). We disregard occurrence information because $P_1$ has symptoms for one type of headache. Table 1 is the confirmability degrees between symptoms and diseases, and Table 2 is the degrees for $P_1$’s symptoms.

If we don’t consider the composite symptom, from Table 1 and 2, $<\mu_{T}(P_1, d), \nu_{T}(P_1, d)>$ of three types of headache is $<0.5, 0.3>, <0.2, 0.6>, <0.3, 0.5>$. Hence, patient $P_1$ could be diagnosed to suffer from migraine with 50% degree of membership.

On the other hand, if we consider the composite symptom, $<\mu_{T}(P_1, d), \nu_{T}(P_1, d)>$ of three types of headache is $<0.6, 0.3>, <0.2, 0.7>, <0.2, 0.7>$. Comparing three fuzzy labels, as a result, we can diagnose that patient $P_1$ suffers from migraine with 60% degree of membership.

(Example 2) Patient $P_2$’s symptoms are (M5, M8, M18, M19) of migraine, (T3, T5, T10, T14) of tension

<table>
<thead>
<tr>
<th>symptom</th>
<th>migraine</th>
<th>tension</th>
<th>cluster</th>
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<table>
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<tr>
<th>symptom</th>
<th>M18, M22</th>
<th>M3, M15</th>
<th>M8</th>
<th>M5, M12</th>
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<tr>
<td>degree</td>
<td>$&lt;0.8, 0.1&gt;$</td>
<td>$&lt;0.7, 0.2&gt;$</td>
<td>$&lt;0.6, 0.2&gt;$</td>
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headache, and (C4, C11, C13) of cluster headache, and he/she has no composite symptoms. In this example, we consider occurrence information of symptoms because P2 has symptoms for 3 types of headache. Table 3 is the confirmability degrees, and Table 4 is the degrees for P2’s symptoms. Table 5 is the occurrence proportion of symptoms for P2’s diseases.

As given in Table 3 and 4, \[ \mu_T(P_2, d), \nu_T(P_2, d) \] of three types of headache is \( (0.6, 0.3), (0.5, 0.3), (0.4, 0.3) \). Hence, patient P2 could be diagnosed to suffer from migraine with 60% degree of membership and tension headache with 50% degree.

On the other hand, \[ \mu_T(P_2, d), \nu_T(P_2, d) \] of three types of headache considering the occurrence proportion (Table 5) is \( (0.62, 0.28), (0.52, 0.28), (0.61, 0.09) \). Here for example \( 0.61 + 0.09 = (0.4 + 0.3) \cdot 0.7 \) of cluster headache, is calculated as follows:

\[
0.61 = 0.4 + [1 - (0.4 + 0.3)] \cdot 0.7,
\]

\[
0.09 = 0.3 - [1 - (0.4 + 0.3)] \cdot 0.7.
\]

As a result, we can diagnose that patient P2 suffers from migraine with 62% degree of membership, cluster headache with 61% degree, and tension headache with 52% degree.

6. Conclusion

In this paper, fuzzy set theory has been applied to make a medical diagnosis of headache. First, we have developed an improved interview chart with fuzzy degree assigned to the relation among symptoms and three types of headache and suggested an improved diagnosis measure using occurrence information. Then, we have proposed a medical diagnostic method of headache using this new interview chart and measure. Finally, we have illustrated two case examples. The result of the examples indicates that it is possible to classify headache using our diagnosis methods, that is, we can differentiate patients according to the types of headaches they suffer from. We expect that the method will be improved to be an efficient tool for medical diagnosis and the physician’s decision.

There are also several remaining problems for the future explorations. First, we should consider more types for generalization, even if the types considered in this study are the most common types of headache. It also requires a program module for computer-based diagnosis system.

References