# Fuzzy Inference in Medical Diagnosis

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ABSTRACT

In medical diagnostic process we are dealing with the preliminary diagnosis based on the interview chart. We will quantify the qualitative information of a patient by dual scaling and establish both prototypes of fuzzy diagnostic sets and the fuzzy linear regressions. Its utility is shown in the diagnosis of headache and CAFDDH.

## 1. Introduction

In medical science the diagnosis can be regarded as a label assigned by the physician to describe and synthesize the medical status of a patient. It is based on the information the physician collected about the patient and his present knowledge of medical sciences. He generally gathers the infoemation, so-called symptoms, of the patient from the past history, the interview, the physical examination, laboratory results and other investigative procedures such as X-ray and ultrasonic. In the face of uncertainty concerning both the observed symptoms of the patient and the relations of the symptoms to a disease entity, the physician cannot avoid imprecision and uncertainty to determine the diagnostic label that will entail the appropriate therapeutic decision. Moreover, if the physician collects the qualitative information from the interview or the past history, the diagnosis is more complex and imprecise. Nevertheless, the physician is still quite capable of drawing conclusions from this information.

Recently physicians take careful attention to precise definition of what and how they are measuring and how to describe the diagnosis with quantitative scale. It is clear that more complex scales require even more joint effort as in the design of CADIAG-2, a computerized system for diagnostic assistance. It is desirable to work with statistical and fuzzy reasoning, even though the physician often quantifies the qualitative data only by his medical knowledge and experience.

In this paper we are dealing with the preliminary diagnosis from the information of interview chart. The past history and the interview can be the most important tool in establishing the diagnosis for the patient. We quantify the information based on the interview chart by dual scaling and will suggest how to establish the prototype of fuzzy diagnostic sets and how to classify new patients to one of disease by the estimated fuzzy linear regression and fuzzy principal component linear regression. We will use this method to make five fuzzy differential diagnostic sets for headache..

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## 2. Classical diagnosis and fuzzy diagsnosis

When evaluating the patient from the information of interview chart, the physician already determines different weighted values for multiple-choices compatible with each disease. After summing up the weighted values concerning with the patient in each of labels, he determines the label of a patient with the maximum value. In this classical diagnostic process some drawbacks are indicated: summing-up with independent relations between symptoms and personal weighted values for multiple-choices. The fuzzy set framework has been utilized in several different approaches to modeling the diagnostic process by Sanchez, Smets, Adlassnig and etc. Sanchez represents the physician's medical knowledge as a fuzzy relation between symptoms and disease. Adlassnig elaborates on this relational model in the design of CADIAG-2, in which he proposes two types of relations between symptoms and disease : an occurrence relation and a confirmability relation. An alternative approach related to this paper is the modeling of diagnostic process by fuzzy cluster analysis. This type of technique is used by Fordon and Bezdek, and Esogbue and Elden.

In this paper we will apply Nishisato's dual scaling to qualitative information and the prototypes of differential diagnostic sets are obtained by the medical knowledge and fuzzy linear regressions for non-fuzzy data[4]. Below we summarize basic procedures about them.

Suppose that data matrix F is classified typically in diagnostic labels by the physician's knowledge and experience. We can determine the row vector Y and the column vector X by dual scaling, which is based on two principles of internal consistency and constant proportionality. Each component of a vector Y is corresponding to a wieghted value of a patient and a vector Y is divided into clusters, i.e., labels as already indicated by data matrix F, with approximately one degree of membership and a vector X is corresponding to weighted values of multiple-choices. Y can be explained by some components of X and the estimated Y can be inferred by linear combination of components of X. We can determine fuzzy trapezoidal numbers by the medical knowledge and fuzzy linear regressions, i.e., fuzzy labels of disease. More details are shown in references[4,8]. As the vector X is multi-dimensional, it can be reduced by principal components. We are interested in fuzzy clustering with generalized objective function[12] and Fuzzy c-means method[11], by using principal components. The physician will confirm these labels by simulated experiments and clinical data.

## 3. Fuzzy diagnostic model for headache

Seventy-six percent(76%) of women and 57% of men report at least one significant headache per month, and over 90% have experienced a headache in their lifetime[3]. Headache is a frequent presenting complaint in the emergency department and it is worthy of analyzing the interview chart. We have already established the interview chart for five categories of headache, such as tension-type(1), migraine(2), mixed type(3), cranium and neck(4) and vascular headache(5). This chart consists of 46 multiple-choices in 13 items as shown in Table 1 and a patient ought to answer one of multiple-choices in each item.

In our simulated data 200 patients are typically classified in five groups (40,40,40,40,40). The data matrix F consists of 200 rows and 46 columns. By dual scaling we obtain three solutions which explain the information of data

approximately over 86%, i.e., 35% for the first solution, 28% for the second and 23% for the third ,respectively. In these solutions we can find symptoms mainly concerned to each of five labels of headache and these are nearly consistent with the physician's knowledge and experience. Fuzzy trapezoidal numbers can be inferred by the physician's knowledge and the estimated fuzzy and principal component linear regressions. Also we can predict the weight of a new patient by linear regressions in Appendix A. We construct five fuzzy labels of headache from three solutions shown in Fig.I. If a patient checks a headache evaluation format, the physician can find the label of headache as well as the mainly concerned symptoms by Computer-Assisted program of Fuzzy Differential Diagnosis of Headache. Let us consider a datum of a patient such as (3, 2, 2, 2, 1, 4, 2, 1, 2, 3, 3, 4, 2), which shows X13=X22=X32=X42=X51=X64=X72=X81=X92= XA3=Xb3=XC4=XD2=1 and other variables are all 0. From the estimated fuzzy linear regressions for three solutions we obtain ( 0.99, 0.14, 0.45). Comparing with the five fuzzy labels in Fig. I, the patient is ill with tension-type headache(1) with 86% degrees of membership. Of course, we can show the above result by our computer program "CAFDDH".

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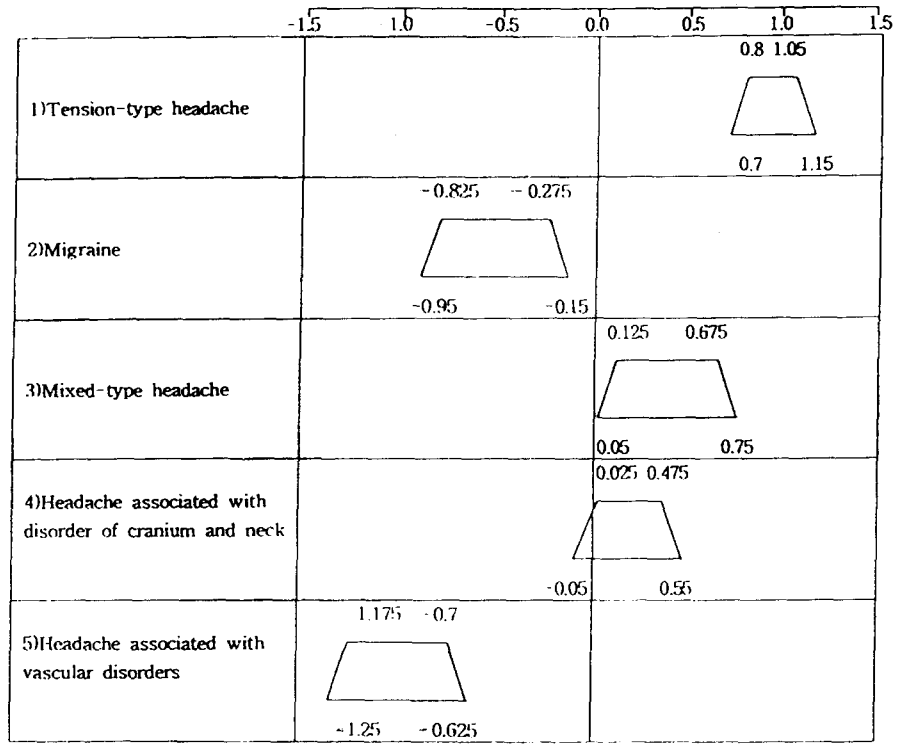
Table I. Headache evaluation format

| | Item | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | duration of individual attack | 30 min - 3 hrs | 4 hrs-3 days | 4 days - 7 days | more than 8 days | |
| 2 | location | global | bilateral | unilateral | | |
| 3 | frequency of attack | 1-4 # / month | 10-15 # / month | daily or almost daily | | |
| 4 | quality | pulsating | pressing / tightening | pulsating + pressing /tightening | | |
| 5 | associatied with symptoms | depression | nausea and vomiting | neck pain | fortification scotoma | face, arm or shoulder paresthesia |
| 6 | associated with signs | motor or sensory abnormality | nuchal rigidity | loss of consciousness | muscle intention | |
| 7 | temporal profile | abruptness of onset | chronic progression | chronic, non-progressive | | |
| 8 | onset | age 10 - 40 | age 50 - 60 | more than 60 | | |
| 9 | family history | positive | negative | | | |
| 10 | precipitating factors | stress | menstruation | firm pressing head | walking stairs | |
| 11 | relieving factors | analgesics | rest | gentle pressing head | sleep | |
| 12 | associated with medical or surgical history | hypertension or atherosclerosis | heart disease | head or neck trauma | mood disorder | no medical or surgical history |
| 13 | severity | mild | moderate | severe | | |

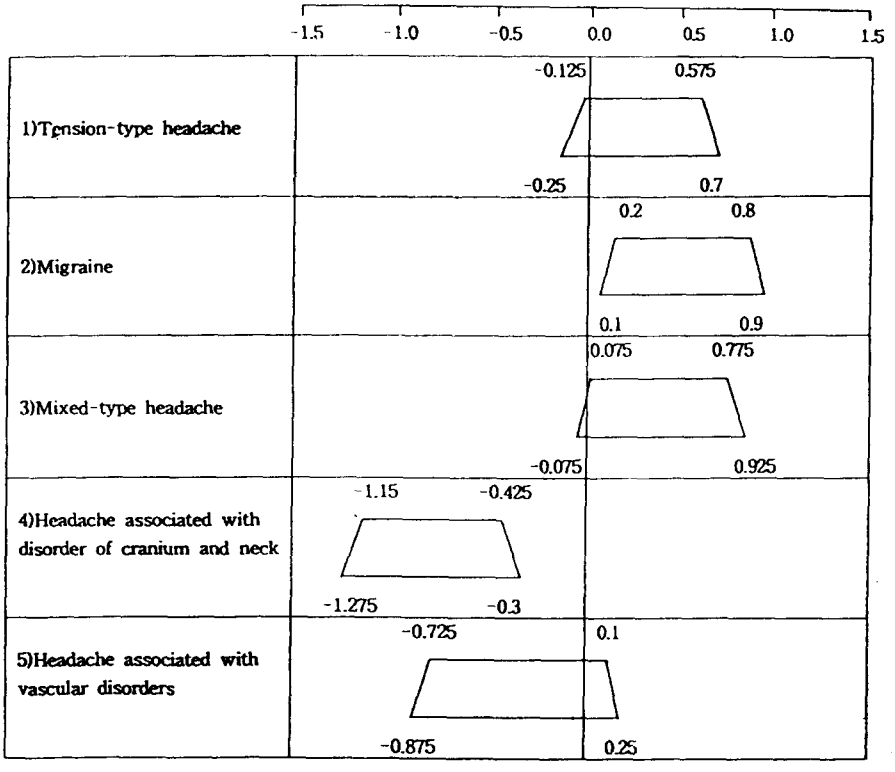
Impression

1. Tension-type headache
2. Migraine
3. Mixed type headache
4. Headache associated with disorder of cranium and neck
5. Headache associated with vascular disorders

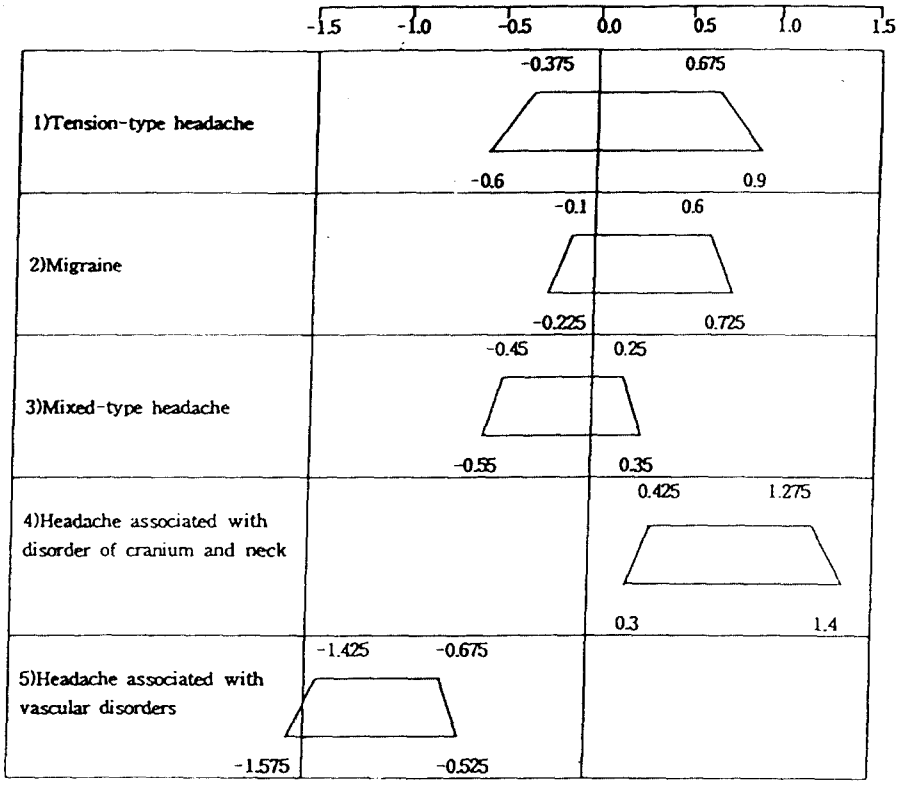
Fig.1 Five fuzzy labels of headache




(1) Five fuzzy labels from the first solution




(2) Five fuzzy labels from the second solution




(3) Five fuzzy labels from the third solution

Appendix A

| Variables | Solution 1 | Solution 2 | Solution 3 | Variables | Solution 1 | Solution 2 | Solution 3 |
|---|---|---|---|---|---|---|---|
| INTERCEPT | 0.757846 | -0.246078 | -0.107990 | X72 | 0.000000 | 0.154704 | 0.000000 |
| X11 | 0.152709 | -0.005803 | 0.000000 | X73 | -0.038325 | 0.000000 | 0.108569 |
| X12 | 0.000000 | 0.017385 | -0.010808 | X81 | 0.000000 | 0.004361 | 0.288102 |
| X13 | 0.114455 | 0.000000 | 0.000000 | X82 | 0.026875 | 0.000000 | 0.000000 |
| X14 | -0.150908 | 0.040289 | 0.000000 | X83 | -0.041214 | -0.219192 | -0.211805 |
| X21 | -0.045126 | -0.031015 | 0.022243 | X91 | -0.019579 | 0.205320 | 0.000000 |
| X22 | 0.000000 | 0.000000 | 0.000000 | X92 | 0.000000 | 0.000000 | 0.056375 |
| X23 | -0.178750 | -0.122900 | 0.088077 | XA1 | -0.022346 | -0.091946 | -0.173915 |
| X31 | 0.000000 | -0.061588 | -0.251043 | XA2 | -0.164041 | 0.000000 | 0.000000 |
| X32 | 0.000000 | 0.000000 | 0.000000 | XA3 | 0.000000 | -0.280254 | 0.066517 |
| X33 | -0.197093 | 0.109940 | -0.992782 | XA4 | -0.163618 | 0.001212 | 0.000000 |
| X41 | -0.459118 | 0.406161 | 0.000000 | XB1 | -0.101940 | -0.020764 | 0.126284 |
| X42 | 0.000000 | 0.000000 | 0.000000 | XB2 | -0.004331 | 0.000000 | 0.010776 |
| X43 | 0.000000 | 0.000000 | 0.913013 | XB3 | 0.000000 | 0.055713 | 0.000000 |
| X51 | 0.207892 | 0.311075 | 0.000000 | XB4 | -0.031742 | 0.026890 | -0.086172 |
| X52 | 0.051925 | 0.089162 | -0.243031 | XC1 | 0.000000 | 0.000000 | 0.000000 |
| X53 | 0.093841 | -0.254427 | 1.351605 | XC2 | 0.000000 | 0.000000 | 0.000000 |
| X54 | 0.000000 | 0.000000 | -0.222551 | XC3 | 0.000000 | 0.000000 | 0.000000 |
| X55 | -0.063924 | -0.339044 | -0.409301 | XC4 | -0.005247 | 0.000000 | 0.152202 |
| X61 | -0.114713 | 0.000000 | 0.238778 | XC5 | -0.118222 | 0.198213 | 0.000000 |
| X62 | -0.250540 | -0.003806 | -0.033887 | XD1 | 0.000000 | 0.179024 | -0.461675 |
| X63 | -0.219558 | 0.100922 | 0.085119 | XD2 | -0.081585 | 0.000000 | 0.000000 |
| X64 | 0.000000 | 0.140470 | 0.000000 | XD3 | -0.197964 | -0.162179 | 0.317556 |
| X71 | -0.202451 | 0.106884 | 0.000000 | | | | |