RHINOS: A CONSULTATION SYSTEM FOR DIAGNOSES OF HEADACHE AND FACIAL PAIN

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ABSTRACT

How do doctors make diagnoses based on their medical knowledge? In this paper a hypothesis is proposed concerning a diagnostic method used by doctors. The knowledge for the hypothesis has been provided by an authority In the field of medicine, and a diagnostic system for headache and facial pain, named RHINOS, has been implemented using the programming language Prolog, which is operative on an NEC PC-9801 microcomputer. Because it is operative on a microcomputer, RHINOS is portable and readily available.

RHINOS has four kinds of rules: two levels of rules perform as forward links from manifestations to diseases. It also has disease-images that act as backward links from manifestations to diseases. It also has disease-images that act as backward links from diseases to manifestations. Through harmonious use of this knowledge, RHINOS makes not only single diagnosis but also makes differential-diagnoses. It also diagnoses cases of complications of two or more diseases. The disease-image link made this possible.

RHINOS was used to diagnose 60 patients and 82% of its diagnostic results were equal to those made by a specialist, 16% were close to those made by a specialist. This shows that RHINOS is capable of diagnosing patients in almost the same way as a specialist.

I INTRODUCTION

Recently, many new ways of clarifying patients' conditions have been introduced to clinical settings. They have enabled doctors to diagnose more precisely and more objectively. However, anamneses and physical examinations are still important, especially In some fields where other information about patients is hard to obtain. Without adequate knowledge or experience in such fields, no doctor can make a precise diagnosis. Therefore, if a diagnosing mechanism containing the knowledge of doctors having the necessary knowledge and experience were represented and programmed into a computer, doctors with less experience would be able to make diagnoses precisely through the assistance of the computer.

Prior to creating a diagnosing mechanism and Installing medical knowledge into a computer, one must clarify what kind of knowledge expert doctors use and how they go about diagnosing patients. To illustrate this point, the authors developed a hypothesis about the way expert doctors make diagnoses. And based on the hypothesis, the authors acquired knowledge from expert doctors, programmed the diagnosing mechanism and the knowledge Into a microcomputer. The authors constructed "RHINOS" (Rule-based Headache and facial pain INformatbn Organising System) as an application of their hypothesis, and evaluated the system using authentic clinical casea(Mataumura 1984).

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With regard to inference mechanisms of medical consultation systems, one can find a production system with certainty factor used in MYCIN(Shortlffe 1976), and a causal network used in CASNET(Weiss and Kullkowskl 1078) and CADUCEUS(Pople 1982). RHINOS uses rules as forward links from manifestations to diseases, and classifies these rules Into four categories according to their degree of certainty. RHINOS also uses disease-images as backward links from diseases to manifestations. By harmoniously Integrating these two kinds of knowledge, RHINOS makes diagnoses almost as precisely as expert doctors.

II DIAGNOSING MODEL IN RHINOS

Let d/(/=1,2,...) be all diseases on earth at past, present and future, and let S_f be sets of manifestations of all patients of each disease. And assume that *S,* is a subset of S1, which comprises all elements that are already known. Also assume that a patient's manifestations are r. Diagnosing can be said to be an Inference of "Which S/* includes r," Judging from the Information of S_f. Expert doctors acquire knowledge necessary to make this Inference from S/, which are sets of known manifestations of the past *d1*.

The authors created the following five categories of knowledge to use as Inferences.

A. Definite Rule (D-Rule)

According to this type of rule, if all manifestations listed in the premise part are fulfilled, the patient is suffering definitely from the disease Indicated.

Example:
If Nature of pain — throbbing pain (1)
History since onset — paroxysmal repetitive (2)
Prodromal syndrome — scintillation scotoma (3)
Concurrent neurological sign during paroxysm — none (4)
Then
This case is definitely a classic migraine.

If any Item In the premise part (1)-(4) is lacking, it cannot be concluded that this is definitely a classic migraine. The authors call this situation as "Premise part Is locally minimized."

D-rule is defined as follows.

A necessary and sufficient condition for manifestation-set *r* to be a premise part of a D-rule for disease *d/* Is

1. $Sa(r,d_i)=1$,
2. for any s which is $s \subset r$,

$$Sa(s,d_i) \neq 1,$$

where,

$$Sa(r,d_i) = \frac{card(\{s \mid s \in S_i, r \subset s\})}{\sum_n card(\{s \mid s \in S_n, r \subset s\})}$$

($card(A)$ is a number of elements of set A.)

The authors call Sa(r,d/) a "Satisfaction Index" for manifestation-set *r* and disease *d,*. The second condition Indicates that the premise part is locally minimized.

B. Strongly Suspect Rule (SS-Rule)

According to this type of rule, if an item of the premise part are fulfilled, the patient will probably have the disease indicated, but there is also a slight chance that It could be another disease or other diseases.

SS-rule is defined as follows.

A necessary and sufficient condition for manifestation-set r to be a premise part of an SS-rule for disease d/ Is

1. $e \leq Sa(r,d_i) < 1$,
2. for any s which is $s \subset r$,

$$Sa(s,d_i) < Sa(r,d_i),$$

where e Is a constant relatively close to but less than 1.

C. Weakly Suspect Rule (WS-Rule)

According to this type of rule, if an items of the premise part are fulfilled, the patient may have the disease indicated but there is also a certain probability that it is another disease or other diseases. The purpose of this rule is to prevent the omission of cases in which patients with disease d/ were not caught by D-, SS- or WS-mles of said disease. However, the WS-rule must maintain uniqueness in diagnosing disease d/. Therefore, the WS-rule for disease d/ may be multifaceted for the purpose of covering a wide range of disease d/, where D- and SS-rule for disease d1 are unique.

The WS-rule Is defined as follows.

A necessary and sufficient condition for a set *Rj,* which comprises manifestation-sets *r1* to be the premise part of the WS-rules for disease d1 is

1. for any $r \in R_i$,

$$e^{*} < Sa(r,d_i) < e,$$

2. for any $r \in R_i$, for any s which is $s \subset r$,

$$Sa(s,d_i) < Sa(r,d_i),$$

3. $e^{**} < Co(d_i)$,

where,

$$Co(d_i) \equiv \frac{card(\{s \mid s \in S_i, \exists r \in R_i \cup R_i^{*} : r \subset s\})}{card(S_i)}.$$

(Ri is a set whose elements consist of the premise parts of D- and SS-rules for disease d/.)
(e* Is a constant which is close to but less than e.)
(e** Is a constant which is close to but less than 1.)

The authors call Co(d/) a "Covering index" for disease d/.

D. Associate Rule (A-Rule)

After focusing on a disease through the application of the D-, SS- or WS-rules, this rule makes more probable the system's diagnostic belief.

Example:

Middle-aged women often suffer from classic migraine headaches. However, the system cannot diagnose the allment as a classic migraine simply because the patient is a middle-aged women, nor, conversely, can It reject the poeslbMlty that it is a classic migraine merely because the patient is male. But If other evidence suggested that It was a classic migraine, the fact that the patient Is a middle-aged women makes more probable the system's diagnostic belief.

E. Disease Image

This shows all the possible manifestations of disease d/.

Example:
Age — over 6
Sex — male or female
Pain location — whole head, half of the head, frontal, temporal, parietal, occipital, or suboccipital
Nature of pain — throbbing pain, continuous pain, or bursting pain

With these five kinds of knowledge (A through E above), RHINOS makes inferences, whose sequence Is described as follows. (Assume that s Is a manifestation set of a patient.)

1. If the D-ruie of disease d/ matches the patient's manifestations, (which means that the premise part of the D-rule is a subset of or equal to 5), and s Is a subset of or equal to a set of disease-Image of d/, the system will Indicate that "The patient is suffering from d/."

2. If the SS-rule applies (in the same manner as described In number 1 above), the system will state that *"dj* is strongly suspected."

3. Likewise, if the WS-rule applies, then the system will state that "There is some possibility of d/."

4. If the D-ruie of disease d/ matches the patient's manifestations, but s is NOT a subset of nor equal to the disease-image of d/, the system will state that "This Is a complication of *dj* and other diseases."

6. If the SS-rule of disease d/ matches, but s Is not a subset of nor equal to the disease-image of d/, the system will state that 'This is a complication of d/ and other diseases, or this is not d/."

6. If the WS-rule of disease d/ matches, but s is not a subset of nor equal to the disease-image of disease d/, the system will state that 'This is a complication of d_f and other diseases, or this is not d/." In this case, however, the possibility of the latter Is greater than that of the former.

7. In steps 5 and 6, If no D-rule, SS-rule, nor WS-rule of any disease other than d/ matches, the system will state that 'The possibility that this is not d/ is reduced."

8. If any of the D-, SS-, or WS-rules of disease d/ matches the patient's manifestations, and If the A-rule of disease *dj* matches, the system will state that The certainty of the diagnosis Is strengthened."

There Is a slight chance that the patient may be suffering from d/ but that, having completed the sequence above, the system may make Inappropriate diagnosis when none of the D-, SS-, or WS-rules of d/ matches the patient's manifestations. The probability of this case Is evaluated using the Covering-Index as,

$$E = \sum_{n} \{1 - Co(d_i)\} P(d_i)$$

where, *P{d1*) is an a *-priori* probability of disease d/.

In order to prevent Inappropriate diagnosis, the following step has been added.

9. If s is a subset of or equal to the disease-Image of disease d_{it} the system will state that "d/ must be differentiate." meaning that the provisional d/ Indicated cannot be ruled out yet, pending additional Information.

If s is a manifestation of one single disease, the above warning will be Issued in order to avoid oversight. However, If s is a combined manifestation of multiple diseases and s Is not specific enough for these diseases, the system will make Inappropriate diagnosis. This may be prevented through the classification of disease-Image (e.g. exclusional disease Image, Inclusional disease image, etc.). It must be remembered, however, that In such cases, even a medical specialist may experience difficulty in making precise diagnosis.

III KNOWLEDGE ACQUISITION PROCEDURE

The knowledge required for the system was acquired from medical expert through algorithm shown in fig. 1. The amount of knowledge extracted through this procedure and the number of steps executed can be enormous. But each step of the procedure is rather simple.

IV RHINOS SYSTEM PROFILE

A. Diseases that can be diagnosed by RHINOS

RHINOS is aimed at patients whose chief complaint is headache and or facial pain. The classification of headache and facial pain used by RHINOS was derived from a classification of such pain drawn up by a committee of six American specialists chaired by A. P. Friedman in 1962(Friedman 1962). For convenience of inference, the authors then reclassified the Information Into 36 diseases. First depth classification of diseases are following 13.

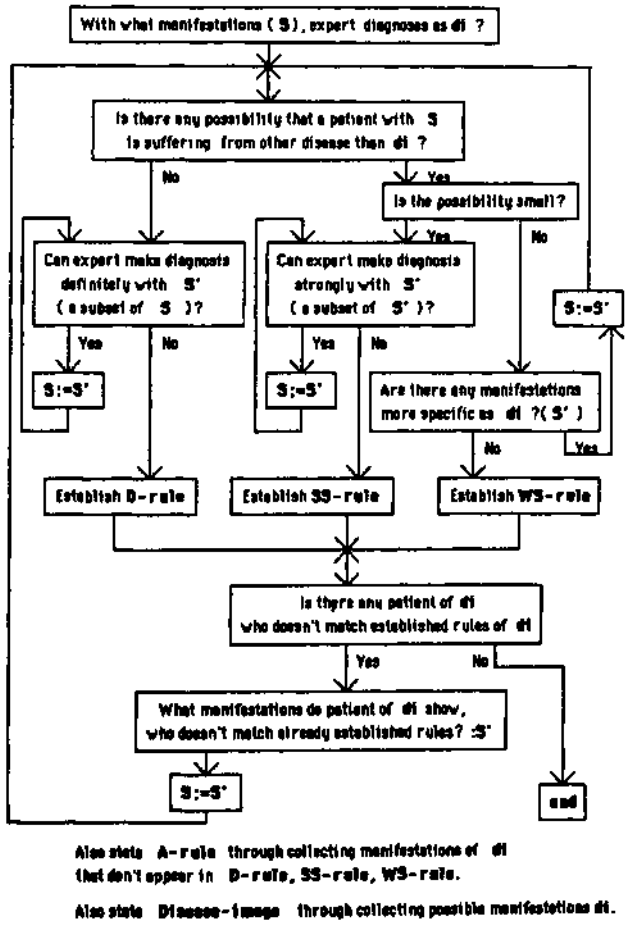

fig. 1 Algorithm for Knowledge Acquisition

1. Intracranial diseases
2. Muscle contraction headache
3. Vascular headache
4. Neuralgic headache and facial pain
5. Psycogenlc headache and facial pain (In narrow sense)
6. Inflammation of the eye (Including glaucoma)
7. Ear diseases
8. Nasal sinus diseases
9. Jaw joint and teeth disease
10. Nose diseases
11. Invasive diseases to the skull
12. Craniocervical anomaly
13. Arteriosclerotic headache

B. Working environment

RHINOS is implemented by a programming language Prolog-KABA(Sakuragawa 1984). All the knowledge used in RHINOS is represented in a predicate-logic manner of Prolog. The pattern matching feature of Prolog is a very efficient and useful function, which makes the retrieval and evaluation of information quick and convenient(Kimura 1983).

Prolog-KABA is operative on CP/M-86 on NEC PC-9801 microcomputer (CPU: 8086, RAM extended to 266 KB). This means that diagnosis can be carried out through medical consultation system RHINOS on hardware costing less than JYE400,000 (~ US$1,500). Retailing RHINOS Is planned in a near future. The maximum CPU time for one case does not exceed 1 minute. No user is needed to wait for the microcomputer response longer than 20 seconds at any scene.

C. System architecture

RHINOS is comprised of four parts: Input, Knowledge base, Inference engine, and Output.

1. Input

RHINOS first requires that Information on the following 15 Items be screened.

Age
Sex
Pain location
Nature of the pain
Severity of the pain
History since onset
Frequency of the paroxysm
Duration of the paroxysm
Prodromal syndrome
Concurrent neurological sign during the paroxysm
Interval of the paroxysm
State of sleep
Ratio of present pain severity to the past severest period
Tender spot

After acquiring information on these 15 signs, RHINOS applies rules for the case. If more Information Is required by the system, additional questions will appear on the screen.

2. Knowledge base

The knowledge base of RHINOS Is mainly comprised of five kinds of knowledge, described earlier In this paper. The number of rules and Images are as follows.

D-rule, SS-rule, WS-rule: 126
A-rule: 67
Disease-Image: 36

3. Inference engine

Procedure of Inference sequence was described earlier In this paper (see II).

4. Output

Output Is not a final diagnosis but a list of the possibilities from the view of anamneses and physical examinations. An example is given in fig. 2.

V EVALUATION

Fifty cases of patients whose chief complaints was headache and/or facial pain were surveyed at Kansai Medical College, Department of Neurosurgery. A comparison was then made between the RHINOS diagnosis and that of a human expert (Professor of the department), whose diagnosis was based on the medical records of anamneses and physical examinations only.

In 40 out of 50 cases, both the RHINOS' and the doctor's diagnoses coincided. In the 10 other cases the following problems arose:

Type 1. RHINOS did not rule out a disease the expert ruled out. (6 cases)

Type 2. RHINOS stated 'This case may be disease *d1* but manifestation *m,* can't be explained." The expert rejected this possibility. (2 cases)

Type 3. RHINOS stated only one disease with "manifestation m*j* can't be explained" The expert concluded that the case was a complications of two diseases. (1 case)

Type 4. RHINOS could not provide conclusive information because the disease was very rare and no existing rule applied to that disease. (1 case)

Type 5. The medical record was apparently erroneous. (1 case)

Actually, there is no serious problem in Type 1. Even in Types 2 and 3, RHINOS provided a suggestion for the right answer. Discarding Type 6, the authors reacned the following conclusions:

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++++++++++++++++ RHINOS Diagnostic Conclusions ++++++++++++++++++++++++++

## ARTERIOSCLERDTIC HEADACHE is stronalv suspected. ##

Because
  History since onset          : Wavy continuous
  Nature of pain               : Continuous pain
                                 Diurnal variation
  Sclerosis of retinal artery  : Yes
  Pain aggravated              : Especiallv in the morning.

Furthermore,
  Tenderness                   : A1 (right) (definite pain)
                                 A1 (left) (definite pain)
  Jolt headache                : Answer was Just after Jolting
these manifestations strengthen the certaintv of this diagnostic belief.
------------------------------------------------------------------------

## There is some possibilitv of INTRACRANIAL MASS LESION. ##

Because
  Jolt headache                : Answer was Just after Jolting.

But this diagnosis cannot explain the following manifestations:
  Sclerosis of retinal artery  : Yes.
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## There is some possibilitv of SYMPTOMS OF OTHER DISEASES. ##

Because
  Ratio of present severitv of pain compared to past severest period
                               : More than 5/10
  History since onset          : Wavy continuous
  Jolt headache                : Answer was Just after Jolting.

Furthermore,
  Tenderness                   : A1 (right) (definite pain)
                                 A1 (left) (definite pain)
these manifestations strengthen the certaintv of this diagnostic belief.

But this diagnosis cannot explain the following manifestations:
  Sclerosis of retinal artery  : Yes.
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Following diseases must be differentiated:
  AUTONOMIC DISTURBANCE
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Fig.2 RHINOS Consultations

Coincided with the expert: 82%
Answered with little discordance: 16%
Discordance: 2%

The result show that RHINOS is capable of providing almost the same as a human expert. However, the following problems still remain.

1. The disease-image of RHINOS is a set of manifestations of a disease that can arise, but the disease image of a human expert Is far more complex. This made It impossible for RHINOS to rule out a disease that the expert ruled out.

2. Because manifestations of headache and/or facial pain are rather subjective, a certain amount of ambiguity must be accouted for In the Information obtained. The human expert put emphasis on the key manifestations, which he then reconfirmed in many ways in order to get the Information as correct as possible. RHINOS does not do this.

VI FINALING REMARKS

RHINOS is now used mainly by the resident staff in the office of the Department of Neurosurgery. It is also used as CAI for students. The portability of the system, as well as the quality of consultation, enhanced the actual use of this system.

As noted before, In order for this system to make more precise diagnoses for patients suffering from more than one disease, the introduction of classifications of disease-image (necessary image, sufficient image, exclusionary Image, etc.) will prove effective in diagnosis.

The authors are already planning some other improvements on the system. It is planned for RHINOS to focus on and reconfirm key manifestations that are fundamental to diagnosis.

The authors are already planning some other improvements on this sytem. It is planned for RHINOS to focus on and reconfirm key manifestations that are fundamental to diagnosis. Plans also exists for RHINOS to suggest, 1) what laboratory examinations be examined in order that a more precise diagnosis may be achieved; and, 2) methods of treatment beyond diagnosis.

In this project, the authors confirmed their hypothesis to the domain of headache diagnosis, even though It was a subjective-fact oriented domain. Being so close to the fundamental procedure of doctors1 diagnoses, this hypothesis can be applied to other diagnostic domain as well.

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