THE INTELLIGENT SYSTEM OF THE HEARING INVESTIGATION

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Abstract: This paper describes a prototype of the intelligent system of the hearing investigation developed by the Tver State Technical University. The problem of automatic diagnostics, considered as the recognition problem of object not completely determined on set of the diseases classes' descriptions, is discussed. The management strategy of the hearing investigation is proposed.

Keywords: hearing investigation, recognition of object.

1. Introduction

On modern stage an integration problems of patient condition investigation strategies and diseases diagnostics are most actual in the field of medical informatics. Realization of such strategy allow raise accuracy of the diagnostics and shorten time and examination cost. In report the realization way of similar strategy are considered as example of the creation of intelligent integral system, controlling the investigation process and diagnostics of the hearing organs. Majority of strategies use the hearing indirect estimations resulting from patient sensations. In this connection investigation strategies adaptation must be provided to patient in this area of medicine. Necessary to take into account its intellect possibilities and ability of the correct self-awareness. This particularity and the using of qualitative factors for the hearing estimation intensify the subjective nature of the hearing organs investigation results. The latter sufficiently complicates the task of the disease diagnostics because practically only subjective and qualitative information is attracted for its solution.

2. The Composition of system and information models.

The intelligent system of survey and the hearing diagnostics includes five subsystems: the information, the expert- diagnostic, the investigations, the planning and the training. In report main attention is spared of the investigations subsystem and subsystem of diagnostics.

The information subsystem is meant for automated record-keeping of the patient's history as well as organization of interconnection as of all software blocks.

The expert diagnostic subsystem is created on the basis of the concept of intelligent expert systems and is meant for automated formation of diagnostic conclusion hypotheses by means of patient's condition estimation. The main function of the subsystem are: results analysis of separate tests and their collection; analysis and recognition of the audiograms type; patient model analysis and search in the knowledge-base of relevant rules; formation of the diagnosis hypothesis; output of preliminary conclusion as of the hearing investigation results; formation of the conclusion about the disease development course based on the investigation results for the whole observation period; connection with database of diseases histories.

The audiometric investigations subsystem is meant for automated testing of the patient by software realization of methods of tone and speech audiometry.

The training subsystem allows automate the procedures of explanation to patients of strategies of the hearing investigation.

The subsystem of treatment planning is meant for information support of remedial measures, automatic generation and successive correction of the investigation plan and treatments of patient.

3. Management of investigations and stating the diagnosis

The strategy and management algorithms of interconnected processes of investigation and the hearing diagnostics are created on the base of gradual development process analysis of physician's knowledge (the systems) about patient. Considering its temporary distribution, problem of automatic diagnostics can be referred to the recognition problem of object not completely determined on set of diseases classes descriptions.

Let, $S_i^* \subseteq S_i \quad , S_i \in V_{PN_i}$, where S_i - is a cortege of diagnostic signs, assigning description of patient on overbroad investigation, S_i^* - is a cortege of diagnostic signs, assigning patient description as a result of not completed investigation, PN_i - is a set of symptoms classes descriptions (in private event a class can define the disease).

Moreover, if $(\exists j) \quad S_i^* \cap S_j \neq 0 \;$ and $\; S_i \cap S_j \neq 0$, that obviously on given step of investigations S_i^* there are symptoms, which typical of not single disease.

To recognize of object, not completely determined, necessary to find classes most close to S_i^*. The methods and algorithms of decision of such problems are defined by the manners of assignation and determining of measures of resemblance and differences in space of signs values.

Let measure of resemblance between objects S_i and S_j will be nonnegative material function $C(S_i, S_j)$, which has limit, increases with growth of objects vicinity and possesses the following characteristics [Andreischikov,1998]:

$$\left\{\begin{array}{c} 0 \le C(S_i, S_j) \le 1 \text{ when } \quad i \neq j \\ C(S_i, S_j) = 1, \quad \text{full resemblance} \\ C(S_i, S_j) = \quad C(S_j, S_i) \end{array}\right\} \tag{1}$$

Let give the similar determination of the difference measure $D(S_i, S_j)$:

$$\left.\begin{array}{c} D(S_i, S_j) \ge 0, \quad i, j \in \Im \\ D(S_i, S_j) = 0 \qquad \textit{full resemblance} \\ D(S_j, S_i) = D(S_i, S_j) \\ D(S_i, S_j) \le D(S_i, S_k) + D(S_k, S_j) \end{array}\right\} \tag{2}$$

Form of concrete function C (S_i, S_j) is know to depend on scales of signs measurements and purposes created categorizations [Larischev, 1998; Zagoruko, 1999]. The resemblance characteristic on the Chekansky-Serensen's formula is measured by the simple equation:

$$C(S_i, S_j) = \frac{2m(S_i \cap S_j)}{m(S_i) + m(S_j)} \tag{3}$$

where: $m(S_i)$ - is the number of binary signs, entered in object description, $m(S_i \cap S_j)$ - is the number of the general binary signs, presented in descriptions S_i, and S_j , $m(S_i \cup S_j)$ - is the total number of binary signs in descriptions S_i, and S_j.

The conclusions from correlation (3), got on artificial samples of objects, well coincides with qualitative interpreting of resemblance notion. Approximately such result is got on the base of Kulchinsky's formula:

$$C(S_i, S_j) = \frac{1}{2} \cdot m(S_i \cap S_j) \cdot \left[\frac{1}{m(S_i)} + \frac{1}{m(S_j)} \right] \tag{4}$$

Coincided signs are taken into account only once in formula of Gakkar:

$$C(S_i, S_j) = \frac{m(S_i \cap S_j)}{m(S_i \cup S_j)} \quad (5)$$

This measure, calculated by modified formula, is provided in Polovinkin's work [Polovinkin 1998]:

$$C(S_i, S_j) = 1 - \left[\frac{m(S_i \cup S_j) - m(S_i \cap S_j)}{m(S_i \cup S_j)} \right] \quad (6)$$

Estimation of resemblance (5 or 6) in contrast with (3) is less sanguine.

The Gakkar's adjustments are preserved in Sokal-Sinet's formula, as well as attempt to intensify importance underbar (discriminating) signs is undertaken:

$$C(S_i, S_j) = \frac{m(S_i \cap S_j)}{2m(S_i) + 2m(S_j) + 3m(S_i \cap S_j)} \quad (7)$$

The quantitative estimation of resemblance, formed by (7), is else lower, then on Gakkar's formula.

The estimation of function, received on Andreev's formula, several is uprated:

$$C(S_i, S_j) = \frac{4m(S_i \cap S_j)}{m(S_i) + m(S_j) + 2m(S_i \cap S_j)} \quad (8)$$

To estimate of differences between objects we use the metrics of type:

$$D(S_i, S_j) = m(S_i) + m(S_j) - 2m(S_i \cap S_j) \quad (9)$$

The formulas (1- 9) install the measure of resemblance between objects described by conjunctive functions. In the more general event the vicinity measure determination of object towards some class is described by conjunctive-disjunctive function of type:

$$PON_i = PON_i^k \,\&\, PON_i^D \quad (10)$$

Conditional distance between single object and class is valued by hierarchy of function δ_i:

$$\delta_i = \sum_j, \sum_j = \sum_{j-1} + r_i, \qquad j = \overline{1, m}$$

where: under j=1 $\sum_j = 0$, m – is the number of attributive features in object model:

$$S_i = \underset{j=1}{\overset{m}{\&}} P_j^0$$

$$(\forall j) \quad r_1 = \left\{ \begin{array}{lc} 1, & P_j^0 \cap PON_i \neq 0, \quad P_j^0 \in PON_i \\ 0, & P_j^o \cap PON_i = 0 \end{array} \right\} \quad (11)$$

Thus, δ_1 characterizes amount of binary signs (values of multivariate signs) from model of object S_i, which entered into description of class PON_i.

Restriction (10) imposing on structure of class description, reinforcement of function δ_i is provided:

$$(\forall j)\, r_2 = \left\{ \begin{array}{l} 1, \quad P_j^0 \cap PON_i^k \neq 0, \quad P_j^0 \in PON_i \\ \qquad 0, \quad \textit{in rest events} \end{array} \right\} \quad (12)$$

Consequently, δ_2 characterizes amount of binary signs (values of multivariate signs) from model of object S_i , which fall into description of function PON_i^k only, that is to say these signs are general signs for all objects of class PON_i.

The relative factor of use frequency of any feature P_j^0 in class description is defined by means of:

$$\delta_3 = \frac{\delta_1}{m}$$

Since, δ_2 characterizes the coincidences number in descriptions of object and function PON^k, that δ_4 will define respective relative factor: $\delta_4 = \delta_2 / n_1$.

If $PON_r^k = \mathop{\&}\limits_{i=1}^{m} P_{ij} \quad and \quad PON_r^k \subset PON_r \quad and \quad S_r = \mathop{\&}\limits_{i,j} P_{ij}$, that

$$(\forall j)\, r_5 = \left\{ \begin{array}{l} 1, \ \ (\ni k) \ \ P_{ik} \in PON_r, \ \ P_{ij} \neq P_{ik}, \ \ P_{ik} \in \overline{P_i} \\ \quad (\overline{P_i} \quad set\ of\ multi\mathrm{var}iate\ sign\ value) \\ \qquad\qquad 0, \quad in\ rest\ events \end{array} \right\} \qquad (13)$$

Consequently, δ_5 will characterize number of multivariate signs from model description of object S_i, values of which fall into function PON $_r$.

The Analysis (3.28 - 3.30) shows that given features allow to value:

- δ_1 - is the absolute vicinity of object S_i toward class PON_i on number of coincided features;
- δ_2 - is the local vicinity of object S_i toward class PON_i in the field of strict generality, (characterizes number of signs P_j , entered in the strict generality in description of analysed class);
- δ_3 - is relative vicinity of object S_i toward class, (takes into account coincidence of features and length of description of analysed class);
- δ_4 - is the relative local vicinity of object S_i toward analysed class PON_i;
- δ_5 - is the typical vicinity of object S_r toward class PON_r on count of alike signs (in multivariate event $f(P_{ij})$ on background of possible variations their value).

For example, we have certain factor δ_{ij}, characterizing vicinity measure not completely determined situations S toward some class of objects V_j. Let, a rule: " if $\delta_{ij} = 1$, that object belongs to the class $S_i^* \in V_j$; if $\delta_{ij} = 0$, that situation has nothing in common with class V_j ", is equitable. If $\delta_{ij} < 1$, that object S_i^* has some general signs with class V_j . Logical function PN_i , which takes the different true values on set $\{S_k\}$, is know to exist and to be determined obviously. Assume that classes PN_r and PN_t are most close for S_i^* in size δ_{ij}.. These classes are known to be not cross, and at least one sign value, falling into description as PN_r so and PN_t, exists.

Situation vicinity degree S_i^* to each class can be different in general event. Assume that $\delta_{ir} > \delta_{it}$, i.e. S_i^* closer to class Vr. Then inverse correlation $d_{ir} < d_{it}$ for co-equivalent feature $d_{ir} = 1 - \delta_{ir}$, defining differences between object and class, is equitable.

The Features, being general features for class PN_r and situation S_i^*, defines the subset $I = \overline{PN_r} \cap \overline{S_i^*}$, $\overline{PN_r} \setminus I = D_i$, where $\overline{PN_r}$, $\overline{S_i^*}$ - is the set of signs values, being arguments of functions PN_r and S_i^* accordingly. The set D unites values of signs, falling into class determination PN_r , but not being present in S_i^* . The separation of features, distinguishing situation, not completely determined, S_i^* from class PN_r , allow build the management strategy of investigation (and diagnostic) on base of minimization of vicinity function δ_{ij}.

Proposed strategy of investigation management includes the following stages:

- Creation of i description of patient condition in the manner of situation, not completely determined and given in signs space.
- Separation of classes subset, closed to under investigated object S_i^*; degree of vicinity is the adjusted parameter (δ_{ij})
- Analysis of classes specifiers for the reason revealing the set of object signs, not determined within the framework of model of i approximation (S_i^*).
- The forming of managing influence:
  - the choice and activation of investigation strategy for determining certain signs
  - the forming of information messages with lists of the not yet defined features and recommendations on the plan of investigation for the physician.
- The correcting of the patient description: $S_i^{**} = S_i^* \bigcup P_m^0$.
- The checking of vicinity functions: if δ_{ij} = 1 ($S_i^{**} = S_i$), that purpose of management is reached, otherwise cycle is repeated with the preliminary actualization of all subsets.

Conclusion

Designed algorithm of management allows integrate the procedures of investigation and diagnostics, shortens the number of features defined in the course of investigation, brings about reduction of temporary expenses.

The first version of intelligent system of investigation and diagnostics of the hearing passes the test in polyclinic of regional clinical hospital in Tver.

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