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Comparison Discriminate Characteristics Rhino Metric Methods of Diagnosis

Husham Farouk Ismail Saied[1], Oleg Grigorovitsh Avrunin [2]
[1]Dept. of AHS, Salman Bin Abdulaziz University/ Saudi Arabia
[2]Dept. of BME, Kharkov National University of Radio Electronics/ Ukraine

Abstract*—This method can be considered as respect to the improvement information-measurement technology alternative control and technical diagnostics. This method allows planning multiple repeated measurement groups, obtained on the basis of non-stationary measurement signals with priori unknown spectral properties. By using the method of piecewise-linear regression approximation of measuring signals allowed obtaining additional information about the changes in random coefficients' partial linear regression .Proposed comparison of discriminant characteristics of rhinomanometry diagnostic methods using the Mahalanobis distance were used to measure the distance between the random vectors of values and generalize the concept of Euclidean distance. Experiments prove that, the proposed method in our work of rhinomanometry measurement at forced respiration has great (1.4 factor) discriminant features in comparison with traditional methods and reduces the possibility of errors when making decisions of diagnostic solutions from 0.17 to 0.06. This allows the use of this method for functional diagnostics of the upper respiratory tract. This work aims to develop methods and criteria that allow the differential diagnosis for pathologies of the upper respiratory tract according to rhinomanometry data.

***Index Terms*—Rhinomanometric Diagnosis AARM And APRM, Norms And Disorders Of Nasal Breathing, Pressure Drop, Air Flow Rate, Static Model, Dynamic Model, Multichannel Measurement Module, Discrimination , Object Control, Discriminate Characteristics, Uncertain Object Characteristics, Uncertainty Conditions, Errors Possibility ,Controlling Objects States, Probability Of Making Correct Decision, Mahalanobis Distance.**

I. INTRODUCTION

In recent decades, a significant increase in prevalence of upper respiratory tract diseases has been recorded. One of the leading places of which is the pathology of the nose and Para nasal sinuses, According to data [1] in Ukraine, more than 10% of the population suffer from chronic inflammation of the Para nasal sinuses—sinusitis. Upper respiratory tract diseases, which most often begin with a disturbed respiratory function of the nose, result in reducing the life quality of patients and may lead to cardiovascular diseases and disorders of the central nervous system. The effectiveness of therapy in this case essentially depends on the quality of the diagnosis and choosing the appropriate treatment strategy [1].

II. THE ACTUALITY OF THE TASK

In studying the most significant functions of the upper respiratory tract, the rhinomanometric method, which involves measuring the pressure drop on the nasal passages and the corresponding air flow rate during breathing, is used [2]. At present, a large number of methods and tools for rhinomanometric diagnostic can be utilized. However, the anatomical features of the upper respiratory tract had complex physiological process of breathing and lack actual standards, leading to the fact that the evaluation of the nasal region, which characterizes the degree of respiratory failure, essentially depends on the method of measurement and has significant variability. Therefore, the actual problem is to expand the diagnostic capabilities of investigation methods and substantiation expediency of application of these methods in the diagnosis of specific pathologies.

III.STATEMENT OF THE PROBLEM

When developing new diagnostic methods and tools, the final step is to compare the discriminate characteristics of the proposed method with the existing ones. In this case, an important task is to select the informative parameters of diagnosis and control, as well as the criterion by which the discriminate features of the methods will be compared. Effective solution of the task of controlling objects states with random properties depends on the correct choice of the maximum informative system parameters (signs) and sensitivity to changes in the characteristics of the object. Any formal control implements the procedures of testing; resulting effectiveness, which determined certainty; and the probability of making the correct decision [3]. Under uncertain object characteristics, the task of selecting informative parameters becomes problematic, especially if complicated metrological support informational transformation in the structure of the system control.

IV. LITERATURE ANALYSIS

Selection of an optimal, by criterion of the maximum certainty, Information System signs- this is classical mission for statistical synthesis under a priori uncertainty conditions [4–6]. Ranking signs on information performed again by the accuracy of control parameters value [7] or errors possibility. [8]

V. THE PURPOSE OF WORK

This study aims to demonstrate the possibility of using criteria parametric models for identification (discrimination) when comparing diagnostic possibilities of using the rhinomanometric method.

VI. THE MAIN PRINCIPLES OF DIAGNOSTIC RHINOMANOMETRY

In modern times, rhinomanometry is performed using specialized computer rhino manometers, allowing the use of automated or semiautomatic modes, to determine the parameters of nasal breathing and carry out a graphic visualization of measurement results [2]. In this case, the classical method of measuring is considered as an active anterior rhinomanometry (AARM) method, performed during quiet breathing and with analysis flow rate data at a fixed pressure drop (300 Pa). The proposed method is active posterior rhinomanometry (APRM), whereas forced respiration allows the estimation of the function of the nasal valve and retrieval of information about specific values of pressure drop and air flow rate, which are very important for sports medicine. Comparison of diagnostic methods has been made on the otorhinolaryngological database of a department in Kharkiv Regional Hospital with the developed device for measuring fall casting-flow rate characteristic of computer KPM type TNDA-PRH (Certificate of state metrological attestation № 05-0102 in 01.04.2010 year). In terms of the composition of this device(as shown in fig.1) included in measuring the unit, containing a differential sensor for pressure dropping between the exit of the nasal cavity and atmospheric, and air flow rate sensor, for air passing through the nasal passages during the breathing process. The latter is based on the principle of the Venturi meter [9]. The signals coming from the sensors arrive and converted into a unit, implemented on the basis a multichannel measurement module L–Card E14–140, the main components of which are steward microcontroller AVR AtMega8515, 14-bit analog-to-digital converter (analog-to-digital converter, ADC) LTC1416 and interface module PDIUSB12D for communication of IBM PC via USB port. The digitized signals from the pressure sensor and flow rate with a sampling frequency of 500 Hz transmitted through the USB interface to the IBM PC for further processing and analysis. The main diagnostic index of the degree of disturbance in nasal breathing at the standard rhino manometer is considered the coefficient of the generalized rate of nasal resistance, K_R

$$K_R = \frac{\Delta P}{Q}, \quad \frac{кПа}{л/с},$$

Which is considered the ratio of measured values (pressure drop ΔP to air flow rate Q). However, when taking into account the coefficient of the generalized assessment of nasal resistance, while determining the discriminate of the properties of the diagnostic methods, additional information does not matter (because it is just the attitude of the measured values), and analysis will be subject directly to distribution of measured parameters: pressure drop and flow rate.

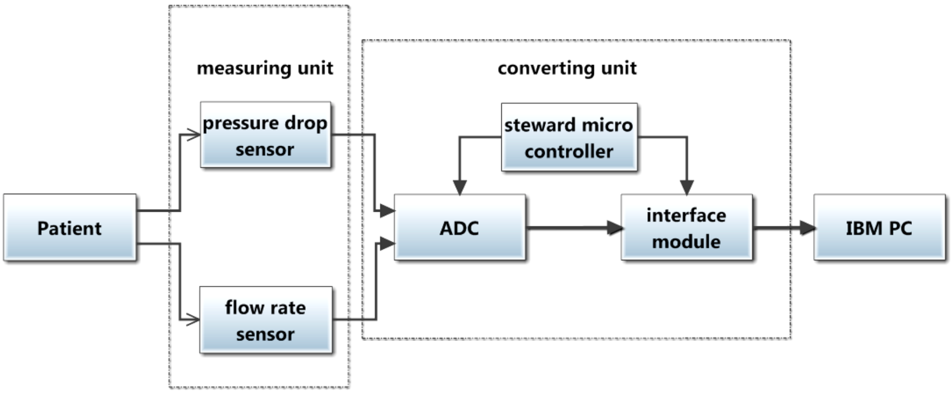

Fig.1 Schematic Diagram of the TNDA-PRH Device

VII. MODEL OF LINEAR DISCRIMINATION

Informative parameter X is used to obtain information about a priori undetermined object control properties and can be considered as a random value. The last, in the case of two object states (Θ_0 - norm, Θ_1 - disturbance norm) is characterized by a condition of probability density distribution

$$X \approx f(X/\Theta_0),\ \text{если}\ \Theta \in \Theta_0,$$
$$X \approx f(X/\Theta_1),\ \text{если}\ \Theta \in \Theta_1.$$

If $m^{(0)}, m^{(1)}, \sigma^{(0)^2}, \sigma^{(1)^2}$ are the average and dispersion values X for conditions $\Theta \in \Theta_0$ and $\Theta \in \Theta_1$, respectively, then under Gaussian distributions $f(X/\Theta_0)$, $f(X/\Theta_1)$, error probability of decision making in the form of an object state is determined at $\sigma^{(0)^2} = \sigma^{(1)^2}$, through the probability integral $\Phi(\cdot)$ [10]

$$P_{error} = 1 - \Phi(\delta/2) \tag{1}$$

Where $\delta = \left|\dfrac{m^{(0)} - m^{(1)}}{\sigma}\right|$ (2)

if $\sigma^{(0)^2} \neq \sigma^{(1)^2}$, then the lower bound for the maximum square deviation of two P_{error} can be estimated by the inequality

$$P_{error} \geq 1 - \Phi(\delta/2). \tag{3}$$

With multiparameter control, when the number of informative parameters $X_1, \ldots, X_n$ more than one ($n \geq 2$) variable δ in expression (1) or (3) described by the following equation:

$$\delta = \sqrt{\sum_{i=1}^{n}\left(\frac{m_i^{(0)} - m_i^{(1)}}{\sigma_i}\right)^2} \tag{4}$$

The square of this variable

$$\delta^2 = \sum_{i=1}^{n}\left(\frac{m_i^{(0)} - m_i^{(1)}}{\sigma_i}\right)^2$$

Is called "Mahalanobis distance," the quadratic distance between the controlled conditions (between the averages vectors on states Θ_0 and Θ_1) [11].

The control object in this case is the vector column of the measured values

$$\bar{x} = \left|\begin{matrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{matrix}\right|$$

with conditional n- volumetric normal density distribution.

$$f(\bar{x}/\Theta_k) = (2\pi)^{-\frac{n}{2}} |\Sigma|^{-\frac{1}{2}} \exp\left[-\frac{1}{2}\left(\bar{x} - \bar{m}^{(k)}\right)\Sigma^{-1}\left(\bar{x} - \bar{m}^{(k)}\right)\right] \tag{5}$$

In equation (5), mean vector $\overline{m}^{(k)}$ and dispersion matrix Σ have the form (k -number of the object state, $k = \overline{0,1}$)

$$\overline{m}^{(k)} = \begin{vmatrix} m_1^{(k)} \\ m_2^{(k)} \\ \cdot \\ \cdot \\ \cdot \\ m_n^{(k)} \end{vmatrix}, \quad \Sigma = \begin{vmatrix} \sigma_1^{\,2} & & & & & \\ & \sigma_2^{\,2} & & & & \\ & & \cdot & & & \\ & & & \cdot & & \\ & & & & \cdot & \\ & & & & & \sigma_n^{\,2} \end{vmatrix}.$$

Expression (4) presupposes the mutual independent vector components in the linear model of discrimination. [11]

The error probability decreased. Then, the bigger δ, the greater the normalization by dispersion squared distance between average vectors.

Thus, variable δ (or δ^2) by the expression (4) allow the quantitative comparison using the discriminating ability (in fact, by information) not only by a single informative signal but by a subset of (system) signals.

VIII. THE PRACTICAL APPLICATION OF THE DISCRIMINATION MODEL

Let us consider the task of effectiveness in assessing two methods of rhinomanometry: method M_a with measurements during quiet breathing and method $M_б$ with measurements in a forced breathing, allowing obtaining the measurement information about the diagnostic status of the object represented:

a) a static model (method M_a rhinomanometry during quiet breathing), and
b) Dynamic model (method $M_б$ rhinomanometry during forced respiration).

In method M_a during quiet breathing, measured physical values (X_1—pressure drop ΔP and X_2—air flow rate Q, the number of measured parameters $n = 2$), as opposed to method $M_б$, are not correlated to the duration of the observation period. State conditional norms and disorders of nasal breathing are denoted Θ_0 и Θ_1, respectively, in all the examined 60 patients, divided into two groups of 30 men: those with normal breathing and those with difficulty in nasal breathing. The measurements for each patient were carried out using the two methods (during quiet M_a and forced $M_б$ inspiration) for ten breaths. In this case and by the general algorithm for each method, the maximum pressure drop ΔP and air flow Q of the upper respiratory tract of patients in each cycle of breath were calculated and were carried out by averaging the ten breaths. Afterward, the statistical parameters for each group of patients were determined: average values $m_1^{(0)} = \overline{\Delta P}$, $m_2^{(0)} = \overline{Q}$, $m_1^{(1)} = \overline{\Delta P}$, and $m_2^{(1)} = \overline{Q}$, respectively, in normal and inappropriate nasal breathing, as well as mean square deviations of the corresponding indexes. Moreover, for calculations, the maximum value of the mean square deviations was selected $\sigma_1 = \max(\sigma_{\Delta P}{}^{(0)}, \sigma_{\Delta P}{}^{(1)})$ and $\sigma_2 = \max(\sigma_Q{}^{(0)}, \sigma_Q{}^{(1)})$, respectively. Furthermore, according to the entered designations, calculations of the Mahalanobis distance by formula (4) and errors probability for decision making by formula (3) for each method were performed. Results are presented in Table 1.

Table .1 Results of diagnosis measurement status for method a) and method b)

Type of method	Traditional method M_a		Proposed method $M_б$	
Status / Parameter	Θ_0	Θ_1	Θ_0	Θ_1
$\overline{\Delta P}$, KPa	0,30	0,3	8,7	16,5

$\sigma_{\Delta P}$,	0,07	0,07	2,25	2,70
$\overline{Q}$, L/S	0,40	0,2	3,10	0,80
σ_Q, L/S	0,07	0,05	0,95	0,43
δ	2,77		3,78	
P_{error}	$\leq$0,17		$\leq$0,06	

IX. CONCLUSION

Proposed comparison of discriminant characteristics of rhinomanometry diagnostic methods using the Mahalanobis distance were used to measure the distance between the random vectors of values and generalize the concept of Euclidean distance. From the results in Table 1, it is clear that the proposed method in our work of rhinomanometry measurement at forced respiration has great (1.4 factor) discriminant features in comparison with traditional methods and reduces the possibility of errors when making decisions of diagnostic solutions from 0.17 to 0.06. This allows the use of this method for functional diagnostics of the upper respiratory tract. The perspective of this work is to develop methods and criteria that allow the differential diagnosis for pathologies of the upper respiratory tract according to rhinomanometry data. Our future enhancement is to develop a multifunctional rhino manometer that must be capable to perform direct rear active rhinomanometry with the specified metrological characteristics and a capability to implement additional indirect methods of diagnostics of air conduction of upper respiratory tract when direct measurements cannot be done. The outlook for the work involves the hardware implementation of the complete device, its metrological attestation, development of patient examination technique to ensure repeatability of results and clear criteria for differential diagnostics of various diseases of upper respiratory airway.

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AUTHOR BIOGRAPHY

Husham Farouk Ismail Saied, 1975. Sudan, Khartoum. B.Sc. Physical and biomedical electronics, Faculty of BME, Kharkov State Technical ytisrevinU of Radio Electronic, Ukraine. M.Sc. in Physical and biomedical electronics, Faculty of BME , Kharkov State technical University of Radio Electronic ,Ukraine. Ph D2010- till this day, student, Dept. Biomedical Engineering, Kharkov State technical University of Radio Electronic, Ukraine. The supervisors in PhD thesis is Oleg Grigorovitsh Avrunin. Published Papers:1-Husham Farouk Ismail Saied and other "Analysis of Changes of the Hydraulic Diameter and Determination of the Air Flow Modes in the Nasal Cavity," Image Processing & Communications, challenges3, AISC 102. Springer- Verlag Berlin Heidelberg (2011) – P. 303-310.(2)- Husham Farouk Ismail Saied and other, "An Attempt of the Determination of Aerodynamic Characteristics of Nasal Airways," Image Processing & Communications, challenges3, AISC 102. pp 303-310 Springer-Verlag Berlin Heidelberg (2011). (3)- Husham Farouk Ismail Saied and other, "The Role of Paranasal Sinuses in the Aerodynamics of the Nasal Cavities," International Journal of Life Science and Medical Research, Sept. 2012, Vol. 2 Iss. 3, PP 52-55. 1 patents for inventions in biomedical engineering field.

Oleg Grigorovitsh Avrunin ,1976.kharkiv,Ukraine, Associate Professor, Dept. Biomedical Engineering, Kharkov State Technical University of Radio Electronic, Ukraine. Scientific specialty: Medical Devices and Systems. Research interests: Design of macroscopic techniques for diagnosis and surgical interventions planning inside the human brain. Technique and methods for medical navigation systems and medical information systems. Technique and methods for diagnosis and surgical interventions planning of the upper respiratory tract. Visualization methods. Imaging techniques for automation processing of medical images and analysis. Author of about 140 scientific papers, of which 26 patents for inventions in biomedical engineering field.