REAL TIME ANALYSIS OF THE NYSTAGMUS AND MOVEMENT PATTERNS IN BALANCE DISTURBANCES

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Abstract :

Balance disorders are difficult to manage in a diagnosis and/or treatment situation.

This article presents an application for the diagnosis of balance disorders in real time, and it has been jointly developed by the LIDI and the Medical Sciences Faculty from La Plata University, and is currently in use at consulting rooms. At present we have already examined more than 300 patients under these systems and controlled them after the necessary treatment.

Patient response processing is emphasized by using signal processing techniques and image treatment in real time, the aim being the obtention of a totally automatic diagnosis.

Keywords:
Computer aided diagnosis - Real time - Diagnosis - Signal processing - Image processing.

1. INTRODUCTION:

As balance disorders are very common symptoms reported everyday by patients, traditional diagnosis methods had to be modernized and adapted to new technologies.

The otoneurological examination is the first step in a research for a diagnosis. It includes a complete neurophysiological examination of the VIII cranial pair (stato-acoustic nerve). The cochlear (auditory) and vestibular (equilibratory) roots are specially considered.

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For the study of the vestibular root of the VIII cranial pair, there is a battery of objective tests (Estelrrich, 1975) They consist of a graphic register of nystagmus (Ny) or ocular movements. The nystagmus consists of a slow deviation movement (to the right or left) from the visual axis, followed by a quick back movement to the rest position. Once the nystagmus are registered, they are recognized and evaluated according to different parameter s such as latency, frequency, amplitude, velocity of the slow and fast components, and direction. The craniocorpography is another test which explores the existence of disorders in the vestibulospinal system.

The aim of this research is to find an objective and automatic method of evaluation of the nystagmus by means of a computerized analysis and its comparison with the craniocorpography.

2. METHODOLOGY:

Three classes of tests were used :

2.1 Rotatory Test

It consists of a servo-commanded rotatory chair that moves during 30 seconds with an acceleration of $3^o/sec^2$, a constant speed of 90°/sec being reached, the patient revolves during 3 minutes, at the end of which the chair is abruptly stopped in 1/3 seconds, i.e., with a deceleration of $270^o/sec^2$. Thus, during the first 30 seconds of stimulation a per-stimulating response with a supraliminal stimulus is obtained; finally, when the rotatory chair is stopped, a post-stimulating response with a supramaximal stimulus is registered during a similar period of time.

2.2 Caloric Test

The patient is stimulated with 20 cm^3 of water at 30°C and 44°C during 30 seconds, the first 180 sec after stimulation being registered (Claussen Tests). The 30 seconds of greatest activity of the nystagmus are selected to represent the dynamics of the reaction. For both caloric and rotatory tests there are parameters differentiating the normal from the pathologic, called rates of normality. From the previous explanation it can be deduced that there are 81 possible results for each test (rotatory and caloric), from which the partial functional diagnosis for each case can be deduced.

2.3 Craniocorpography:

Craniocorpography allows an objective study of body postural reactions during the Unterberger test and the creation of a mathematical evaluation system (Claussen, 1970).

During the Unterberger test, or *in situ* march, the patient must take from 80 to 100 steps on the same place. In order to measure movements, luminous signals related to a polar coordinates system are used.

The lights on the head and shoulders of the patient are the origin, from where forward movements, head and body turnings and head and body oscillations are measured (Claussen, 1973). From this register four parameters can be obtained (Figure I):

1. **Lateral deviation**: Given by the angle between the straight line at the starting position and the line joining this with the line at the ending position.
2. **Distance**: Longitude of the straight line joining the starting and ending points.
3. **Head turning**: Given by the head anteroposterior axis deviation angle at starting and ending position.
4. **Head and body lateral oscillations**: Head and body oscillations longitude for each step taken by the patient.

Mean and standard deviations were determined. The starting position was projected upon the polar coordinates axis, where the 0 degrees reference is taken to the left of the patient, increasing clockwise, the patient looking towards +90°.

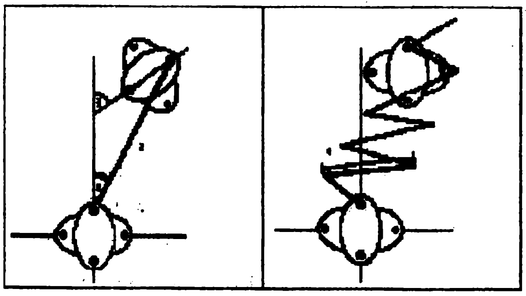

Figure I

The following values were obtained:

Lateral deviation: 100° ± 59°
Distance: 68 cm. ± 30 cm.
Head turning: 113° ± 74°
Lateral oscillations: 10.85 cm ± 7 cm.

These values are used in order to establish the craniocorpography normality parameters. As a summary it can be said:

- Lateral oscillations increase is originated from central alterations (CNS).
- A small increase of lateral oscillations with respect to the normal interval is observed in people over 50.
- Lateral deviation: Mean and standard deviations in peripheral alterations are perceptively distant from the normal interval in all tests.
- Repetition of registers was also studied by means of re-testing during the same session. A remarkable consistency for the repetition of a determined deviation pattern in patients with organic alterations was verified.
- Repetition within bigger intervals was then studied by performing the tests on different days. The correlation coefficient shows the existing relation.

Five typical configurations have been defined for diagnosis (Figure II).

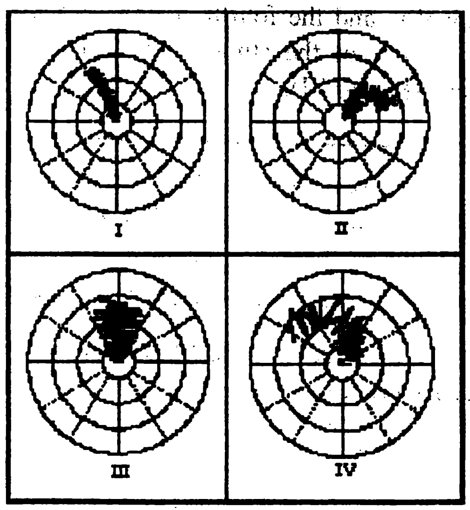

Figure II

Type I: Normal. The patient moves only forward, keeping within the normal interval doing only small amplitude lateral oscillations.
Type II: Peripheral alterations. The patient moves towards the altered side, doing small lateral oscillations.
Type III: Central alterations. The patient moves with big lateral oscillations.
Type IV: Combined lesion. The patient moves with considerable increase of lateral oscillations and marked deviation towards one of the sides.
Type V: Changing kinetic pattern. The patient changes his/her answer to the tests each time. This model allows for feigning and psychogenic vertigo recognition. The feigner cannot re-feign in an identical way.

3. IMPLEMENTATION ASPECTS

3.1 Rotatory and Caloric Test

The response of the patient is digitalized by using an A/D PC Lab 711 converter card with the following characteristics: 12 resolution bits, 65 microsec. conversion speed, 8 input 1 output analogue channels and 16 input/output digital channels.

The test is registered and visualized in real time by means of four channels in the following way: the first one is used for the analysis of the response of both eyes at the same time, the second and third channels are used for the analysis of each eye individually, and the fourth channel is used for a register of the stimulation signal for each test (Figure III).

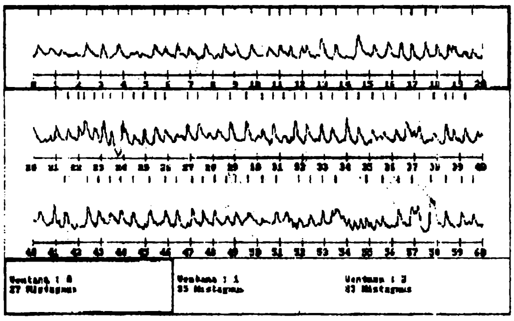

Figure III

Nystagmus identification is the most difficult phase of the processing stage. They are obtained by calculating the inflection points of the sampled signal and then a step by step function derivative is obtained.

Then local maximums are analyzed and assigned to the corresponding nystagmus, acceptable ranges both for amplitude and derivative being considered.

The evaluation of the tests is done by superposition of a graph with premarked normal zones and the results of the patient's test (Figures IV and V):

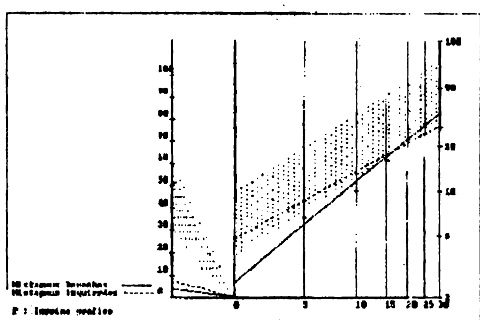

Figure IV

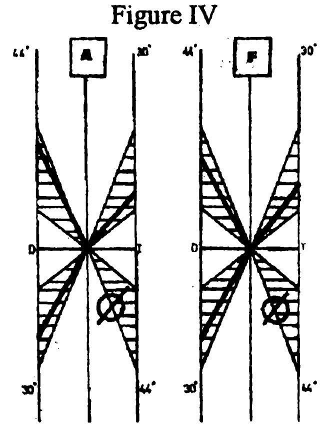

Figure V

These decisions are made in accordance with an experimental criterion based on the specialist previous knowledge, which depends on the global response of each patient.

Since a wave shape determined with very strict identification parameters must be recognized within the signal, sample frequency values should be correctly determined.

Our first experiences were developed using between 30 and 40 values per second, which turned out to be insufficient in the calculations stage. At this moment a sampling frequency of 65 samples/sec. is being used, results being very good due to an improvement of the original signal amplification.

However, during the standardization stage, apart from choosing the suitable calculation method, the optimum frequency has to be determined, in order to reduce calculation time to a minimum.

The language chosen was C, because it facilitates external hardware control and it allows for a direct handling of possible memory (which is a fundamental aspect due to the amount of data to be handled directly in memory in the processing stage).

Each patient is linked to all developed test, a signal reconstruction being thus possible when needed.

A Ny recalculation with a different analysis criterion is possible for each of the graphics presented in the screen.

Each sample includes Ny marking and the obtained results. Thus, for the visualization process of an existing sample no previous calculations are needed.

During the first experimental stage, the results obtained with this system were compared with manually obtained historical results until a high coincidence degree was obtained.

3.2 Craniocorpography:

Image recording for the craniocorpography is realized by using a video recorder placed on the ceiling. Captured images are processed by means of image processing and pattern recognition techniques, which allow an automatic diagnosis by using known statistical patterns (Figure VI).

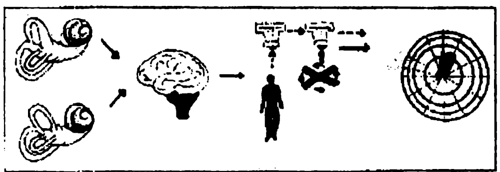

Figure VI

Apart from this, and in order to objectively measure and evaluate the luminous trail, a reference system of polar coordinates has to be set. This is solved by means of a system calibration, taking the patient height as input data.

Diagnosis of balance disorders by means of a craniocorpography involves the following stages:

1. **Acquisition**: An image sequence is obtained, which reflects the patient's behavior during the test. This is registered with a VIDEO BLASTER video card, whose buffer may be accessed by a driver.

2. **Pre-processing**: Each image is processed in real time directly from the video card buffer (Goldsmith, 1993). This processing consists of the reduction of each of the four lights to its central point (medium axis obtention), and the chaining of corresponding dots in successive images using chain codes (Baxes, 1994)(Jain, 1986).

3. **Characteristics Extraction**: oscillation amplitude evaluation and lateral deviation for each of the four signals, which are obtained by following each point through the acquired image sequence.

4. **Classification by means of pattern statistical recognition techniques**: The pattern statistical recognition problem is solved by using an optimum sorter, which assigns x pattern to the w_i class according to Bayes decision rule (Niemann, 1989).

In a two class problem, the decision rule is given by the relation between $P(w_1 | x)$ and $P(w_2 | x)$. That is to say, if $P(w_1 | x) > P(w_2 | x)$ then x is assigned to w_1. If the opposite is true, x is assigned to w_2.

The probability that x comes from the w_i class is represented by the a posteriori probability $P(w_i | x)$\$.

This rule is optimal because it minimizes the classification error, i.e., the average amount of wrong classifications.

The application of the Bayes rule is rather difficult even though the rule itself is quite simple. This is so because the a posteriori probabilities are unknown and therefore have to be estimated.

Specific Developments

The purpose of this work is the implementation of an automatic system for the recognition of patterns corresponding to patients movement during the test, being thus able to classify them among four possible classes of alterations (normal, peripheral, central and combined), which will be considered classes of patterns.

The characteristic features of these patterns are oscillation amplitude and lateral deviation. Thus, the characteristic space is two-dimensional (Figure VII).

As there are superposition areas between classes where perfect classification is not possible, a certain probability of error in the decision making process must be taken into account.

Specifically, a vector with 2x1 characteristics is defined, say x, which represents the characteristics of the entities. We select x1 as a measure of the oscillation amplitude and x2 as the lateral deviation one.

The characteristics of each class are:

w_1 : small oscillation and deviation.
w_2 : big deviation and small oscillation.
w_3 : big oscillation and small deviation.
w_4 : big oscillation and deviation.

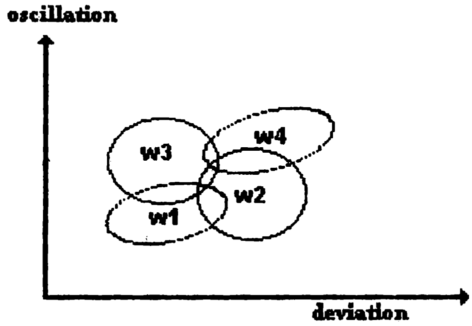

Figure VII

With the results obtained from the previous stage the wi class is identified and a diagnosis is reached.

It should be considered that the two first stages are developed in real time, whereas the last two are realized off line upon the previously obtained data.

5. CONCLUSIONS

The design of a real time system applied to balance problems diagnosis currently in use at consulting rooms has been presented.

The speed and precision obtained with an automatic system like the described one improves the diagnosis of the specialist and accelerates the response of the patient, which is analyzed in a more objective way.

As an example, the complete battery of tests are shown in Figure VIII, where we see an alteration of the central nervous system on the left side. It demonstrates in each test the alteration of the normal patterns.

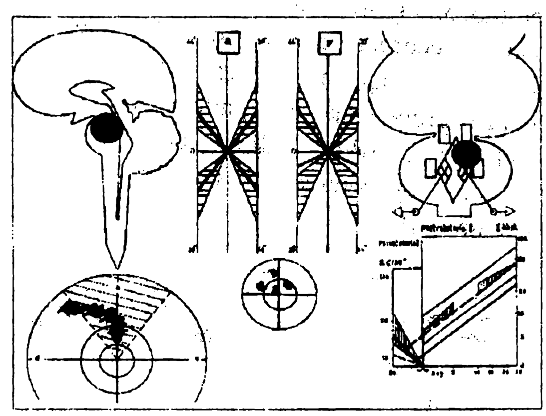

Figure VIII

All documentation concerning this work is available at LIDI: 50 y 115 -1er. Piso - (1900) La Plata - Argentina.

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