THE POSTUROGRAPH APPLICATION IN A DYSLEXIA DIAGNOSIS

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Summary

This paper shows the analysis of possibilities of center of mass projection tracking application in dyslexia diagnosis. The metrological, economical as well as constructional issues of computerized dynamic posturograph (CDP) are taken into consideration.

Keywords: posturograph, computerized dynamic posturography (CDP), dyslexia diagnosis.

KONCEPCJA ZASTOSOWANIA POSTUROGRAFU DO DIAGNOZOWANIA DYSLEKSJI

Streszczenie

W niniejszym artykule dokonano analizy możliwości wykorzystania przebiegu położenia rzutu środka ciężkości na płaszczyznę podstawy do diagnozowania dysleksji. Rozpatrzono aspekty metrologiczne konstrukcyjne i ekonomiczne zastosowania platform posturograficznych.

Słowa kluczowe: posturograf, komputerowa posturografia dynamiczna, diagnozowanie dysleksji.

1. INTRODUCTION

The majority of diagnostic examinations is based on reading and writing tests, therefore its application is restricted to children above 6-7 years old. Earlier dyslexia diagnosis gives children greater chances of normal development by the early start of therapy. The diagnosis is possible only basing on the aspects of child's behaviour. Medical and psychological researches show that dyslexia is indirectly connected to the occurrence of medulla deficiencies. Medulla is responsible for various cognitive and motor processes e.g. acquiring and mastering of new skills, coordination and keeping the body balance. It also plays an important role in a process of learning, detecting and correcting mistakes in motor processes. Medulla deficiencies are also attributed to development al dyslexia. Unbiased diagnostics tests of medulla deficiencies can be therefore helpful in dyslexia diagnosis. The electronic tests are useful in medicine to diagnose dyslexia in children in the pre-school age, they are also useful for legal purposes to verify dyslexia in students taking secondary school leaving exams.

One of the major methods that enables quality measurements of medulla functions quality is *Mirror Drawing test*, MD. The ways to automates the mirror droving test are described in [1] and [2]. The other method of assessment of quality of medulla functions is an analysis of motor coordination related to keeping body balance and analysis of the speed of acquiring of that skill. This test can be done by an electronic device that tracks the projection of the center of mass to the base plane – a posturograph.

2. REQUIREMENTS FOR A POSTUROGRAF

Posturograph should be able to provide the methods for doing various dyslexia diagnosing medulla deficiencies tests. For metrological requirement analysis the tests can be divided into: simple static, static with feedback and dynamic.

The realization of the described tests generates many requirements for parameters of the measurement set. But to generate precise construction requirements the target group of the patients should be also taken into consideration.

These are kids at the pre-school and primary school age, but secondary school students and adults can not be excluded. Therefore posturograph should enable conducting the tests on people weighting 20÷90 kg, and of height of 100÷190 cm and feet length of 18÷32 cm.

To sum up during the tests the frequencies of center of mass oscillations are expected to be no more than few Hz and expected amplitudes are up to 20 cm, expected force exerted on base plane is up to 90 kg. Moreover apart from measurement the techniques for data acquisition and processing need to be designed. The digital signals should be registered for further processing and for automatic diagnosis generation. Additional, but very import ant requirement is the low cost of the apparatus.

3. ANALYSIS OF CURRENT SOLUTIONS

Posturographs are manufactured for and applied in medicine and rehabilitation, most frequently In orthopaedic problems and for diagnosing and treating diseases that disrupt normal body balance keeping skills. The first to explore medical application of the posturograph in Poland was Institute of Measurement Systems and Automatics (currently Institute of Electronic Systems) MUT. Later there were few prototypes. Particularly interesting is the one designed by Military Institute of Aviation Medicine.

Currently broader is the offer of international companies, but software for currently available posturographs can not be used in dyslexia diagnosis. The NeuroCom USA products are used in rehabilitation of patients with dyslexia in the UK, but NeuroCom USA offers no diagnostic software.

Additional the prices of computerized dynamic posturograph sets start from 50.000 zł, what makes it practically impossible for psychologist to use it widely. Therefore it is necessary to design an economic version of posturograph that enables the dyslexia diagnosis.

4. CONCEPTION OF THE DIAGNOSTIC SYSTEM

It the dyslexia diagnosis designed posturograph various functional elements can be distinguished.

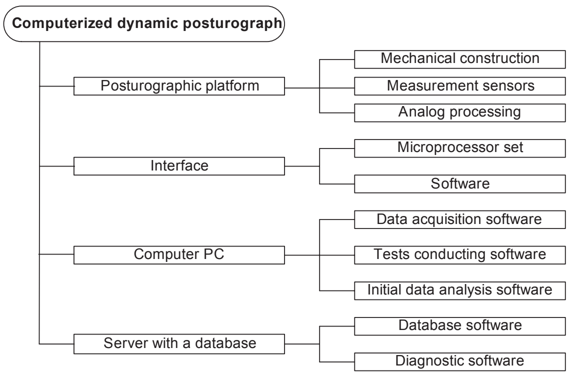

Fig. 1. Functional model of the diagnostics system with the posturographic platform.

The main functions of posturograph, the measurement sensors and analog processing units are: to change the force exerted on the base platform into voltage 0÷5 V and to provide the measurement range for the mass and center of mass position needed for performing these tests. The measurement errors should be below 0,5%, non-linearity of the characteristics below 0,1% time constant of reaction to the unit step below 0,1s.

Interface based on PIC microcontroller with analog – digital converter provides the solution for changing analog signals from the posturographic platform into Digital with frequency above 20 Hz and resolution above 12 bits

Moreover it is responsible for data transfer to the computer by the USC port. The personal computer has to be equipped with software that enables data acquisition by USB port, performing the tests, and introductory analysis of data for dyslexia symptoms. The data from all the tests are going to be send to the server, where the diagnostic software is going to be installed. Storing data on a one server would enable taking into consideration all the tests done by particular individual by diagnosis of the learning speed and abilities. This also provides the solution for investigating correlation with other tests e.g. MD tests, and using the classifiers and learning algorithms on the whole test base.

5. POSTUROGRAPHIC PLATFORM

The Basic models of posturographic platform are designed with three force sensors placed In the vertexes of a triangle or four placed in the vertexes of a rectangle. Platforms with three pivot points enable lower angles of departure from vertical position to be measured. Platforms with four points are prone to disturbance of measurement due to physical irregularities.

In the current project the three point posturographic platform is used but it has a rectangular shape as in figure 2.

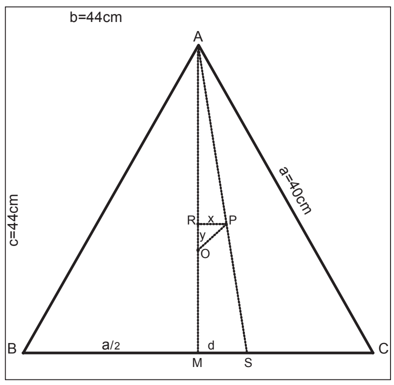

Fig. 2. The dimensions of posturographic platform.

The measurement sensors are placed In the vertexes of a equilateral triangle with edges of 40 cm length. It enables departure of the projection of the center of mass at least for a length of a radius of inscribed circle (r=11,55) cm in any direction from the middle of the platform and at most for the length of an circum circle R=23,09 cm in the direction of one of the sensors.

The most important is the range of the angle of departure from the vertical position of the posture of the examined individual. Assuming that the center of mass of human body is at height of around 60% of the height of the human, the range of measurement of angle of departure from vertical position α is:

$$\alpha = \arcsin\left(\frac{r}{0,6l}\right) \quad (1)$$

where l – height of th examined person.

The ranges of angles measurable by platform with given lengths are : $\alpha \cong 5,9^0$ *for* l=190 cm, $\alpha \cong 10^0$ *for* l=111 cm. In case of children it is going to be sufficient.

In case of frequent exceeding of measurement range the next version of the platform is going to have greater measurement range of the angle of the departure from vertical position. It can be achieved by enlarging the dimensions but it also would decrease the resolution of the measurements.

To measure the force three measurement sensors, installed by Mensor company in the scales they produce were used. Their measurement range is 0÷60 kG, what enables conducting tests on people with weight up to120 kg in case of radius of angle of departure from vertical position r=11,55cm. In the case of using the platform only for testing children it is better to use measurement sensor with range up to 30 kg, which gives the measurement range of posturograph up to 60 kg. It could enable the greater resolution of the measurements.

The measurement sensors of the posturographic platform with the analog processing system generate the voltage proportional to the force exerted on the sensors described by:

$$u_x = u_0 - kF_x \tag{2}$$

where:
u_x – initial voltage for measurement sensor
u_0 – voltage for measurement sensor with $F_x=0$
F_x – the force exerted on the measurement sensor
k – proportionality constant

It is assumed that the proportionality constant k will be constant for all measurement sensors and it will be 1V/20kG and u_0 will be set before every series of measurements in the process of adjusting the measurement sensors.

6. INTERFACE

The initial voltages of theanalog parts of the platform are processed by microprocessor with 12 bit digital-analog converter. Because the range of voltage changes measured do not exceed 4096mV, the12 bit DC converter gives the resolution of 1mV in terms of force it is 20G for measurement sensors with range up to 60kG. The greater resolution would not significantly increase the accuracy of measurement because of the errors of the measurement sensors and other parts of the system.

The AD converter Has a frequency of 20 Hz. This frequency should be enough tracking the changes of the position of center of mass the tests. The dynamic characteristics of platform - the frequencies conducted by the mechanical system is going to be the subject of the research conducted in the near future.

The other functions of the microprocessor are: the data transmission by the USB port and storing In to the computer internal memory. The data transmission is conducted on –line by containing the measurement data from all three channels. It enables the visualization of the projection of the center of mass in the real time, what is necessary for conducting the tests that require feedback.

7. THE ASSUMPTION FOR DATA ACQUISITION AND VISUALIZATION

The function of PC computer is to enable the control of the testing process and the initial data analysis, therefore it should enable: patient's data input or the choice from previously registered data, the choice of test, adjusting the platform, the conversion of the initial voltages into the force and data storage in the file, the conversion of the force into the coordinates of the projection of the center of mass, on-line visualization of the projection of the center of mass, the automatic conductance of the chosen test with the option of control by the operator, the initial data processing that enables the assessment of correctness of the measurements done, the storage of patients' data and tests conducted on the server's database.

All these functions are performer by specialty designer computer program. to convert the voltages into the force this equation is used:

$$F_x = \frac{u_0 - u_x}{k} \tag{3}$$

After the conversion we obtain the sequence of data that represent the forces F_A, F_B and F_C exerted on measurement sensors A, B and C registered every 50ms. Then to visualize and analyze the results basing on the force values the position of the projection of the Center of mass In the classical X,Y coordinates with the middle in the point O is evaluated. The position of measurements sensors and the ex ample of the position of the center of mass is illustrated on the figure 2.

It can be assumed that the projection of the center of mass on the posturographic platform is represented by point P, which distance from point O can be expressed in terms of perpendicular components horizontal – x and vertical –y. Because forces were measured In point A, B and C, the functional dependencies between $x=f(F_A,F_B,F_C)$ and $y=f(F_A,F_B,F_C)$ need to be found.

Using the equalities of momentum in defined position of point P the relation between forces is described by:

$$F_B\left(\frac{a}{2}+d\right) = F_C\left(\frac{a}{2}-d\right) \tag{4}$$

and

$$\left(F_B + F_C\right)\left(\frac{1}{3}h + y\right) = F_A\left(\frac{2}{3}h - y\right) \tag{5}$$

where: a –the length of the arm of equilateral triangle
d – the length of SM segment
h – the height of a equilateral triangle

Using the above equation the equation for the height of the equilateral triangle and the dependency:

$$\frac{d}{x} = \frac{h}{\frac{2}{3}h - y} \tag{6}$$

we obtain the equation for the vertical component:

$$y = a\frac{\sqrt{3}}{6}\frac{2F_A - F_B - F_C}{F_A + F_B + F_C} \quad (7)$$

and the horizontal component

$$x = \frac{a}{2}\frac{F_C - F_B}{F_A + F_B + F_C} \quad (8)$$

Additionally the mass of examined person is evaluated, what is the sum of the forces measured by three sensors:

$$m = F_A + F_B + F_C \quad (9)$$

As a result of the measurements the position of the center of mass can be visualized in the real time or after the test is completed. The examples of characteristics are illustrated on figures 3, 4 and 5.

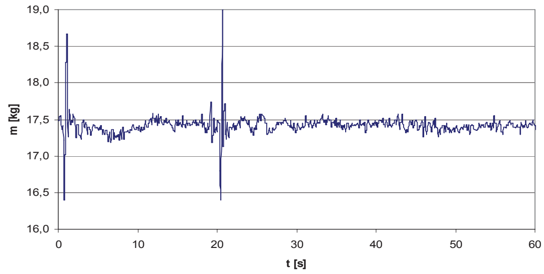

Fig. 3. The graph of the mass as a function of time

The other characteristics can be also drown including the characteristics done by computerize posturographic systems currently available on the market.

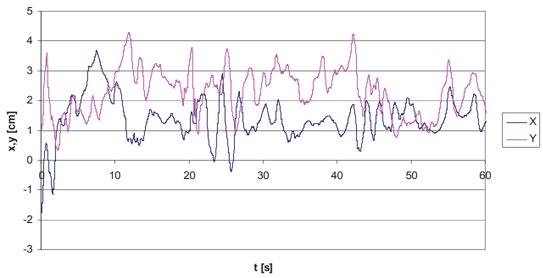

Fig. 4. The graph of X and Y coordinates as a function of time.

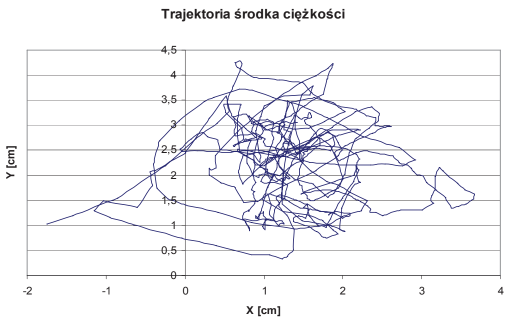

Fig. 5. The graph of the trajectory of the projection of the center of mass on the posturographic platform.

8. THE CONCEPT OF DIAGNOSTIC CONCLUSIONS

The analysis of the single test set can give the initial diagnosis, but the assessment of the speed of the acquiring of the body balance keeping skills can be done only basing on comparison of series of tests. To achieve this a database on the server should be created, where all the results should be stored. It would enable the design of the data analysis algorithms that recognize the dyslexia symptoms basing on maximally large data sample. Moreover it will be possible to evaluate the learning speed, what is one of the major symptoms of medulla deficiencies. basing on many test done by the same person.

The creation of the large database could also enable the large diagnostics analysis based on symptoms occurring in various kinds of electronic tests e.g. posturographic tests and MD tests. Central database would also enables comparison of tests done after few years and verification of the diagnosis basing on real condition of the patient.

As a result of current research the computerized dynamic posturograph has been designed and the prototype set including software has been made. It requires further examination and research on metrological aspects, data analysis and software.

However basing on current results it can be concluded that it gives satisfying results as a research tool and the production costs enable its wide usage. The next steps are further research and creation of database and diagnostics software.

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dr inż. **Wiktor OLCHOWIK** graduated from Faculty of Electronics, MUT in 1985, in the same year he started working as a research and didactic assistant in the Institute of Electronic Systems, MUT. His professional interests include: automatics, computer measurement and diagnostic systems, digital signal analysis. Currently he works for University of Information Technology in Warsaw and Institute of Electronic Systems, MUT.