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Parametrization of handwriting for the assessment of neurodegenerative disorders on the example of Parkinson's disease

***Abstract**. The following paper will present the methodology of determining handwriting parameters, the assessment of which can be used in the diagnosis of Parkinson's disease. The proposed parameters were determined on the basis of the recording of the entire sentence recorded using a graphic electromagnetic tablet.*

Streszczenie.** W poniższej pracy przedstawiona zostanie metodyka wyznaczania parametrów pisma, których ocena może znaleźć zastosowanie w diagnostyce choroby Parkinsona. Zaproponowane parametry zostały wyznaczone na podstawie zapisu całego zdania zarejestrowanego za pomocą graficznego tabletu elektromagnetycznego. (**Parametryzacja pisma odręcznego na potrzeby oceny zaburzeń neurodegeneracyjnych na przykładzie choroby Parkinsona.)

Keywords: handwriting analysis, parametrization, diagnostics, graphic tablet
Słowa kluczowe: analiza pisma odręcznego, parametryzacja, diagnostyka, tablet graficzny

Introduction

Graphomotorics, or handwriting, is a key human skill used in everyday life. The process of creating handwriting depends on the physical and mental predisposition of a person and is closely related to the proper functioning of the central nervous system. This means that the information contained in handwriting can be used to diagnose diseases of the nervous system at an early stage of their development. When writing naturally, there are changes, the analysis of which may indicate the presence and progression of symptoms of the disease [1]. An example of such a disease is Parkinson's disease, which currently affects more than 10 million people. This disease, which is a neurodegenerative disorder, is characterized by symptoms such as resting tremor, limb stiffness, slowness of movement, so-called bradykinesia and instability of body posture [2, 3]. These symptoms, already at an early stage of the development of the disease, can cause problems with writing and thus changes in writing, which may become the basis for the development of diagnostic tests for the diagnosis of the disease [4].

The first papers on changes in handwriting of people suffering from Parkinson's disease focused on the occurrence of micrography [5, 6]. This phenomenon consists in a gradual reduction in the size of the handwriting during writing and is one of the most characteristic changes noticeable in the handwriting of people with Parkinson's disease [7]. The appearance of graphics tablets on the market made it possible to record data on the writing process, which opened up new possibilities for studying handwriting by taking into account the dynamics and kinematics of its creation. Numerous papers were written on the determination of handwriting parameters for the diagnosis of Parkinson's disease [8-16], however, the authors analysed individual strokes or letters, choosing as a handwriting pattern a sequence of the same letters forming loops, words or sentences containing a number of easy-to-define letters. Such approach may introduce some discomfort, distract the examined person or cause excessive concentration, which may affect the results of the analysis of handwriting. In this work, an attempt was made to determine the parameters on the basis of the whole sentence written spontaneously which can be applied in any language. Thanks to this, after writing several identical sentences one under the other, it will be possible to compare the values of the designated parameters between them and on this basis to develop a diagnostic system.

The paper decided to propose such features of handwriting that may expose the existence of specific symptoms of Parkinson's disease. All parameters are based on sentence recording with WACOM's Intous Pro Paper Edition PTH-860 electromagnetic induction graphics tablet.

Fig.1. Intuos Pro Paper Edition graphics tablet by WACOM.

Thanks to the fact that this tool allows you to acquire waveforms corresponding to the position of the pen on its surface, the pressure of the pen on its surface and the tilt of the pen from the vertical, both geometrical, time and pressure parameters have been proposed.

Time parameters

Prolonged sentence writing time may indicate the occurrence of slowness of movement, but it may also result from the need to think longer about the next letter, sign or spatial arrangement of the handwriting. This may indicate cognitive deterioration. Therefore, the total time of writing a sentence is influenced by two components. First of all, the time of drawing signs, i.e. the collection of sample periods when the pen touches a sheet of paper, which may become a feature indicating the occurrence of slowness of movement. Secondly, the duration of the pauses between words, which is related to the time it takes to plan the next move. Therefore, three times can be calculated as time parameters: writing time, that is, the time of plotting visible characters on a sheet of paper; the duration of the pauses between words and the total time, which is the sum of the two above. Figure 2 shows the sentence notation, including the moments when the pen was above the tablet surface.

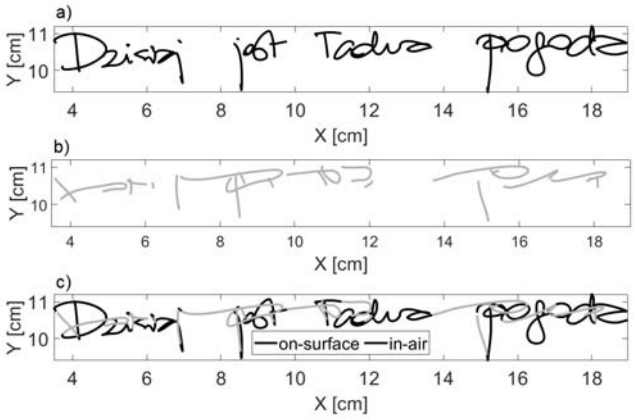

Fig.2. Recorded sentence: a) only samples on the surface of the tablet, b) only samples above the surface of the tablet, c) all samples

Pressure parameters

The presence of symptoms of Parkinson's disease such as resting tremor or limb stiffness can affect the amount of pressure applied to the pen during the writing process. When analysing pressure, it is necessary to take into account not only the average value, but also to quantify the intensity of pressure changes. The calculation of the average of all pressure samples acquired is not sufficiently reliable due to the samples that are recorded when the pen is detached from the paper. To offset their impact, the average value can be determined only from the maxima of the local pressure functions. Having the maxima values of the function, the directional coefficient of the linear function approximating the designated maxima can also be calculated, thus checking the tendency of pressure changes. Figure 3 shows the physical interpretation of the determined parameters.

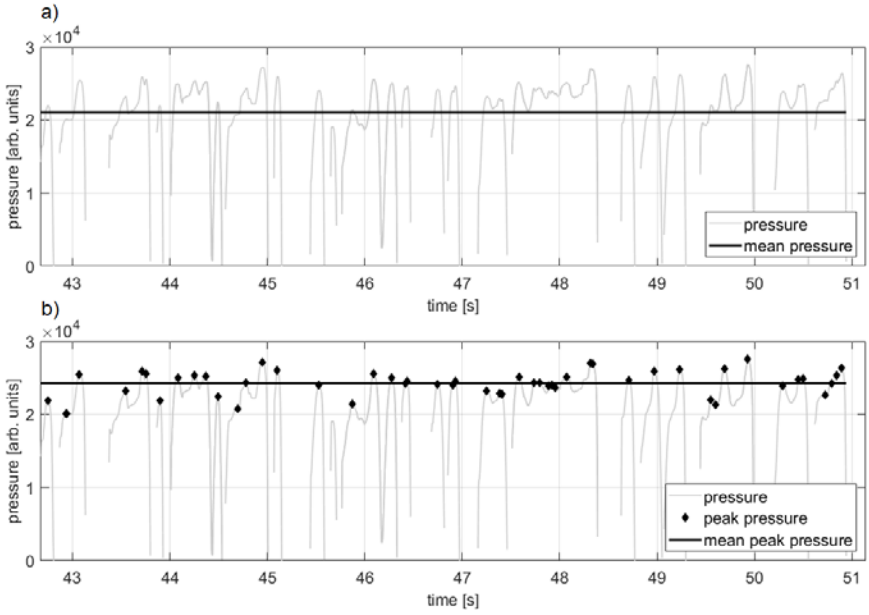

Fig.3. Graph of pressure changes over time with pressure parameters marked: a) mean value of all samples, b) mean value of the maxima of the pressure function

An interesting aspect is also the frequency of detachment of the pen from the surface of the paper when writing. More or less frequent tearing off the pen can also be an indicator of the presence of some symptoms of the disease. In graphology, the so-called writing impulse is determined, which is defined as a quantitative measure describing the frequency of detachment of a writing tool from the ground. The impulse of writing in this work has been calculated as the number of detachments that the writing person made when writing the whole sentence.

Geometrical parameters

Parkinson's disease is most often associated with resting tremor or problems with coordination of movements.

In people suffering from this disease, there is also a kinesthesia disorder, i.e. the sense of orientation, position and movement of parts of one's own body. These symptoms can translate into changes in the appearance of the handwriting, which can be quantitatively assessed using parameters related to the geometry of the handwriting. One of the most characteristic changes noticeable in the handwriting of people suffering from Parkinson's disease is the micrography mentioned above. Therefore, one of the most important parameters that have been proposed in this article is sentence length. On this basis, an attempt can be made to determine the phenomenon of micrography. If the length of the next sentences is smaller than the previous one, it indicates that the font has decreased as the writing process progresses. The sentence length can be obtained by calculating the difference between the extreme X coordinates of the stylus position on the tablet, as shown in Figure 4.

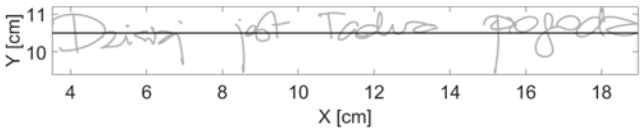

Fig.4. Sentence length without taking into account the tilt angle.

However, in this approach, the tilt angle of the sentence is not taken into account, which can cause misinterpretation. To take into account the slope of the writing to the horizontal, an algorithm based on the linear approximation of all points belonging to each sentence was proposed. However, it should be noted that in order to carry out the approximation, the data should be functional, i.e. for each X coordinate, there should be exactly one Y coordinate. Therefore, a function was created from the received data first. For all X coordinates for which there was more than one Y value, one output Y value was calculated, which was the average value of all. After determining the approximating line using the method of least squares, the

length of the sentence can be assumed as the length of the segment lying on a given line from the first to the last sample of writing, as shown in Figure 5.

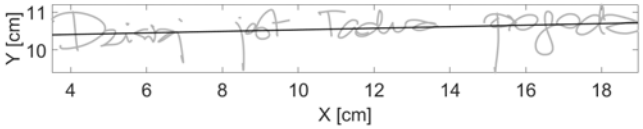

Fig.5. Sentence length taking into account the tilt angle.

Determining a line indicating the arrangement of the sentence on the plane also allows to determine the tilt angle of the sentence itself, using the fact that the directional coefficient of the line is equal to the tangent of the slope of the straight line to the Ox axis.

However, the above method determines the length of the entire sentence, including breaks. If the writing decreases and the gaps between words increase, it will not be possible to clearly determine the decrease in font size. Therefore, the area fields for each individual stroke can also be calculated, and then summed up. The designated areas of individual strokes are shown in Figure 6.

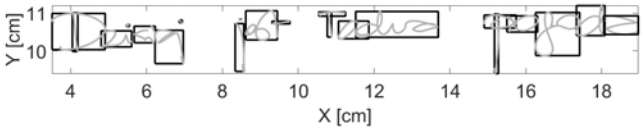

Fig.6. Sentence view with boxes for each pen stroke.

The values of the described parameters for the sentence presented in the work are listed in Table 1:

Table 1. Values of the parameters

Name of parameter	Value
in-air time	2,162 s
on-surface time	6,107 s
total time	8,269 s
mean pressure	21075 arb. units
mean peak pressure	23809 arb. units
peak pressure trend	2,0376 arb. units
writing impulse	21
tilt angle	1,2341°
sentence length	15,463 cm
letters area	8,896 cm^2

Conclusions

The paper presents handwriting parameters and the methodology of their determination, the assessment of which may be used for diagnosis. The authors of similar works focused on determining a very large number of parameters for individual pen strokes. In contrast, in this paper the features were determined on the basis of the transcription of the whole sentence in order to include in the analysis a few words and the spacing between them. In addition, this approach allows you to calculate the proposed parameters for any sentence written in any language. In the early stages of Parkinson's disease, its characteristic symptoms may not be visible during a single sentence record and may not manifest themselves until after a long time of writing. Having the methodology of determining the parameters proposed here, it becomes possible in the future to compare the values of the calculated features for several of the same sentences and observe differences or tendencies resulting from the presence of the disease.

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