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Brain-stem Ultrasound Images Processing and Evaluation

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Abstract: *The ultrasound (US) is well-accessible cheap and noninvasive method used to visualize internal organs. As an information carrier, it uses ultrasonic waves produced by a probe that usually acts as both the emitter and the receiver of the ultrasonic energy. The ultrasonic imagining is based on detecting reflected and scattered waves that are responses to the emitted wave. These waves may have various frequencies. Generally, the higher the frequency is the better and more detailed output image we get. Unfortunately, when we need to obtain the brain-stem US images, used for the Parkinson disease diagnostic, we can only use the low-frequency probes what means we process the images of a low quality. These images have the high importance in Parkinson disease diagnostic and treatment because, except outer characteristics, they are the only way how to determine the existence and seriousness of the disease.*
Processing itself is divided into two parts. In a first one, we try to locate a position of brain stem in the processed image. In the second part, we try to locate and measure small particular objects in the brain stem. In the image, these objects appear as the areas with higher level of echogenicity.

Keywords: *ultrasound, images, processing, brain stem, echogenicity*

1 Introduction

The Parkinson disease (PD) belongs to the diseases affecting mostly older people. It is a chronic neurodegenerative progressive disease that occurs if the nerve cells in a part of the midbrain, called the substantia nigra, die or are impaired. These nerve cells produce dopamine, an important chemical messenger that transmits signals from the substantia nigra to other parts of the brain. These signals allow for coordinated movement. When the dopamine-secreting cells in the substantia nigra die, the other movement control centers in the brain become unregulated [Di Minno, M., Aminoff, M. 2006].

From the diagnostic point of view PD is still a secret for us, because the defunct nerve cells cannot be seen on any medical device but ultrasound system. Except outer characteristics the ultrasound images remain the only way how to determine an existence and seriousness of the disease. The ultrasound itself is well-accessible, cheap and noninvasive method used to visualize internal organs. However it has one big disadvantage, which is a low quality of obtained images [Jan, J. 2006]. Lower quality then means a more problematic diagnostics. It can even lead to a different diagnosis of the same image from two different doctors.

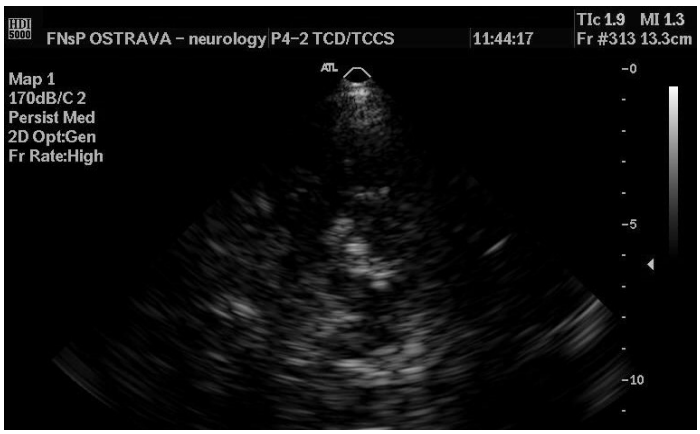

Figure1 – Processed ultrasound image

This is the point when a computer diagnostics may be helpful. According to defined values the computer will always provide the exact diagnosis and any number of processing will always lead to just one result. This way we can remove unwanted subjective influence of a doctor.

2 Brain stem localization

First part of a diagnostics is a localization of brain stem object in the processed image. It has always approximately same shape and size. However a low quality of analyzed images often means that object cannot be very well seen or some of its parts are even missing. A character of the ultrasound which creates images with relatively high level of noise and speckle also means that borders of objects are always discontinuous. More information about ultrasound images processing may be found in literature [Stippel, G. 2005] – [Selbekk, T. 2005].

2.1 Pattern matching method

As a first method for getting a location of brain stem we used a classical pattern matching method. We created a pattern which contained only a window with brain stem object. This patter was in sequence applied to the original image. For each step we counted a result by the equation

$$\varepsilon = \sum\sum\left[b_1(\bar{x}+\bar{u}_i) - b_2(\bar{x})\right]^2 \tag{1}$$

where: b_1 - brightness of pixel in original image I_1 with coordinates $\bar{x}+\bar{u}_i$

$\bar{u}_i$ - denotes a location of processed window in I_1

b_2 - brightness of pixel in pattern image I_2 with coordinates $\bar{x}$.

In the end we determined the brain stem location as a location of processed window with minimal value of ε. However this method did not provide requested results. The problem is that single point with high difference can significantly influence more other points with lower differences. This led us to consider a theory where each processed point can influence result in a same way.

2.2 Brain stem localization using possibility theory

In this method, we look at the problem in a different way [Sojka, E. 2006]. We present a possibility, denoted by $\pi(\bar{x},\bar{u}_i)$, of the event that the template point with the coordinates $\bar{x}$ corresponds to the image point with the coordinates $\bar{x}+\bar{u}_i$. This possibility is determined

from the difference $\Delta b = b_1(\bar{x} + \bar{u}_i) - b_2(\bar{x})$. We suppose that the distribution of this possibility may be described by a chosen function φ. Figure 2 shows an example of such function.

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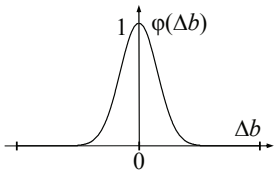

Figure 2 – The distribution of possibility function φ (we use the Gaussian function)

To obtain the possibility of the event that the image pixel just being processed corresponds to the pixel from the template, we use the following equation

$$\pi(\bar{x},\bar{u}_i) = \varphi(b_1(\bar{x}) - b_2(\bar{x})). \tag{2}$$

We introduce the quantity S_Ω characterizing the number of pixels, i.e., the area that can be successfully matched to the template. We have

$$S_\Omega(\bar{u}_i) = \sum_{x\in\Omega} \pi(\bar{x},\bar{u}_i). \tag{3}$$

The obvious goal is to find the value of $\bar{u}$ that maximizes the value of S_Ω. The value of $\bar{u}$ determines the position of the window that should contain the brain stem object as can be seen in Figure 3.

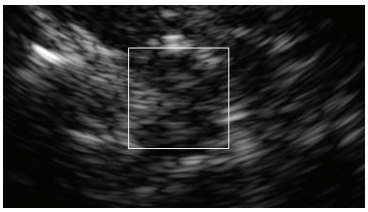

Figure 3 – Image with recognized brain stem object

5 Brain stem diagnostics

To obtain the exact information about the disease progress we now need to locate and measure objects inside the brain stem. Objects are defined as a group of neighboring points where echogenicity exceeds the defined limit. We locate them using a heuristic region growing method. As a next step we remove all objects which we consider to be just a noise or an ultrasound speckle. According to this information we can process recognized window and create the requested output (Figure 4).

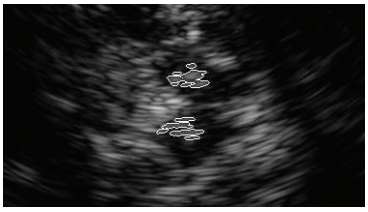

Figure 4 – Group of recognized objects inside the brain stem

6 Results

To test our method, we used a sample of 90 images. We first examined the images ”manually” and, according to their quality, we classified them in the scale between 1 and 3. The mark 1 means that the brain stem is well visible, the mark 2 means that it is visible with some difficulties, and the mark 3 means that it is hardly visible. Then we used our method to locate the position of the brain stem. The result (the quality of recognition) was also classified with the marks between 1 and 3. The mark 1 means that the position was recognized correctly and accurately. The mark 2 means that the position was determined inaccurately but not completely incorrectly. In this case, the position was usually determined with an error up to 10-15 pixels. The mark 3 means that the method determined an incorrect position.

Achieved results obtained during testing make us believe that method we choose is successful. For tested images with a medial and good quality we obtained very good results in localization of brain stem (summarized in Table 1.). This numbers can be further improved by perfecting the template construction and modification of φ probability function.

Table 1. The results obtained for the images of good and medium quality

Quality of recognition	Number of images	result in %
1	47	79,66
2	5	8,47
3	7	11,87

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