1. Introduction

The B-SONO Assist System 1.1 is a MATLAB-based software tool to image processing of ultrasound images. In general, the application is able to use not only for ultrasound imaging but general for any photo. However, this application is focused on digital image analysis in ultrasound imaging. It was tested and verified in clinical practice in neurosonology. Thus, the application is designed as a tool for neurosonologist but can be extended in general. The basic principle of the algorithm lies in using binary thresholding on images in grayscale.

The application has been implemented in MATLAB with using Image Processing Toolbox and subsequently compiled into Win32 EXE stand-alone application by GUIDE.

Requirements

- Operating System Windows XP or newer 32- or 64-bit
- installed Java Runtime Environment\(^1\) 6 or newer (JRE)
- installed Matlab Compiler Runtime\(^2\) 7.14 (MCR)

NOTE: To run the application must be installed JRE because the application using Java. To correct functionality must be installed the exact version of MCR 7.14!

2. Purpose

The B-MODE Assist System software tool is focused on processing and analysis of ultrasound B-images which are a standard mode in ultrasound imaging. B-MODE images are acquired natively in grayscale. Development of the software has been focused on using in neurology to finding some features of Parkinson’s Disease. It was the first idea to develop this software. The application supports DICOM and bitmap image formats. DICOM is a worldwide standard in medical imaging not only from ultrasound (CT, MRI, etc.) and common bitmap formats such as BMP, JPEG, PNG, etc. are supported. This software has been developed as an autonomous decision-based system as follows.

\(^1\) http://www.oracle.com/technetwork/java/javase/downloads/jre8-downloads-2133155.html
\(^2\) http://www.mathworks.com/products/compiler/mcr/
Parkinson’s Disease (PD) is characterized by high level of echogenicity (hyperechogenicity) of substantia nigra\(^3\) in the midbrain. It was the idea to develop this software which could be useful to finding echogenicity level in the ROI of SN by binary thresholding because B-images are natively in grayscale.

**Brief principle of the algorithm**

The foundation of the algorithm is to use binary thresholding in defined Region of Interest area (ROI). The ROI is defined by a user. As mentioned above, the algorithm is based on the idea of finding echogenicity in defined ROI. Binary thresholding is based on a simple idea. Let \(H_i\) is intensity level of a pixel \(i\) and \(T\) is the threshold \(\in (0, 255)\), then

\[
\text{IF } H_i \geq T \text{ THEN } p_i = 1 \text{ ELSE } p_i = 0
\]

where \(p_i\) is the output pixel in binary form represented by Boolean values of 0/1. Thus, the output image is binary image. This process is executed in the defined ROI, for PD is selected ipsilateral or contralateral SN, see Chapter 3.1. At the same time is enabled to select one ROI only.

After the thresholding is computed real \(\text{mm}^2\) instead of pixels. It is the most important information for doctors. In other words, the output represents how many \(\text{mm}^2\) are echogenic depending on thresholding. The result is graphically visualized. See the following flow-chart which describes the principle of the algorithm. Each step is described in Chapter 3 with GUI description.

\[^3\text{http://radiopaedia.org/articles/substantia-nigra}\]
Figure 2 Developed algorithm – flow-chart

3. GUI

The following figure shows GUI of the main window of the application.
The GUI of the application is relatively simple and it is divided into the following sections:

- buttons to load an image
- buttons to select ROI
- adjustable thresholding and coordinates
- execute button
- additional functions and help

**Loading an image and definition of square-shaped window**

These buttons enable to load an image in DICOM or bitmap format. Select a file via standard Windows dialog Open File.

If needed, the image is automatically converted into 8bit grayscale.
Square-shaped window manual or automatic

If the image is loaded, subsequently must be defined a square-shaped window. The size of the window is determined 50×50 mm which is used in TCS images to PD diagnostics. After loading the image you can select automatic or manual position of the window as follows:

- automatized – only click on two points
- manual – click on two points and shift to a correct (desired) position of the window

In automatic version is position is automatically computed depending on input image and its size and resolution. If we use images from the same set, this preset of automatic positioning is useful. The following figure shows the manual shift of the window. The image is displayed in real size.
Click on two points and the distance between two points is computed by Euclidean distance

\[ d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \]

where \( x \) and \( y \) are coordinates of the points.

The selected window is displayed on the main window of the application to select an appropriate ROI depending on examined tissue.

**Selection of a ROI**

![Select ROI](image)
These buttons enable to select ROI which is needed. To PD are used SN ipsi or SN contra (ipsilateral or contralateral subst. nigra). Other ROI:

- LN, CN – ncl. lentiformis, ncl. caudatus
- NR – ncl. raphe (30 mm²)
- delete ROI – enable to delete actual ROI and you can select another

The software was initially developed to PD diagnostics. To this purpose is used SN ROI which is defined as an elliptical region with area of 50 mm² as follows:

Select ROI and shift into a correct position and subsequently double-click on the ROI to fix the position. Now is enabled to run the main algorithm.

**To execute computing**

This button executes the core of the algorithm for selected ROI. Under the selected ROI is displayed binary image and progress of the computing is visualized. Depending on computer power, the computing time is about from 30 up to 50 seconds.
As mentioned above, the algorithm is based on binary thresholding. So, the output represents number of mm$^2$ if $H_i \geq T$ for all $T \in (0, 255)$. In other words, the output shows the number of pixels of which intensity $H_i \geq T$. We get 256 isolated values. See the following figure.

Thus, for each threshold $T \in (0, 255)$ is computed how many pixels have intensity $H_i \geq T$. Red color represents referential values computed from 90th percentile of 100 non-parkinsonic patients. These values have been repeatedly verified by an experienced neurosonologist.

The evaluation of the values is based on:

- comparison measured values with referential values and their subraction
- the SUM value which represents sum of all measured values
Let $V_m$ represents the vector of measured values and $V_r$ is the vector of referential values than difference is given by $V_m - V_r$. The $SUM$ value is given by

$$SUM = \sum_{T=0}^{255} v_T$$

where $v_T$ is the value of the area for $T$. The following figure simply shows the algorithm steps.

![Figure 9 Steps of the processing and output](image)

**To check image quality**

It is very useful part of the algorithm against false echogenicity detection and it is independent on the main processing. The part is realized as a simple multi-agent system. If the input image has high minimal level of brightness could be incorrectly evaluated because very light areas could be recognized as echogenic but in fact are not significantly echogenic. The following figure shows the example of an unsuitable input image and a normal image.

![Figure 10 Increased intensity and normal image](image)

The basic principle of this subsystem is based on dividing the window into 8x8 blocks and for each block is computed intensity corresponding with intensity of neighbor pixels. If this intensity $> 25$, you will see a warning. It could be fatal to correct diagnosis.
Coordinates and adjustable thresholding

On the right side of the main GUI you can see panel of adjustable thresholding and coordinates.

![Adjustable thresholding and coordinates](image1.png)

Figure 11 Adjustable thresholding and coordinates

It is very specific feature of the software. **Adjustable thresholding** allows settings threshold manually to computing. The button **Get ROI** is useful to fix the ROI on specified coordinates **set x-coord** and **y-coord**. It could be useful to investigation of correct position within the same set of images.

Additional functions and help

- **Save 50x50 mm window** – enable to save selected window with ROI
- **Original and equalized** – enable to execute histogram equalization on selected image
- **DICOM info viewer** – simply displays DICOM metadata from a DICOM image
- **About** – about the application
- **Help** – simple help

Additional functions are isolated and are not related to the main functionality.
The following figure shows DICOM metadata extracted from a DICOM file.

![DICOM metadata](Image.Info.000003)

Figure 12 DICOM metadata

### 4. Main advantages of the solution

The following main advantages are crucial:

- independent on input image and its resolution, size and format
- native DICOM files support
- in consideration of B-MODE imaging principle the algorithm can be used not only in neurology
5. Software limitations

This software is designed for MS Windows operating systems only because it is compiled into executable EXE file. If you want to use this application to investigate other structures, each new feature must be conferred with an erudite sonographer.

6. Future Work

This software has been repeatedly tested and verified in clinical practice by experienced neurosonologists. All results were statistically verified by a lot of statistical descriptors such as ROC analysis, correlation analysis and kappa-analysis. These descriptors are needed to evaluate reproducibility and reliability to use in medical practice to diagnosis. The application has been thoroughly tested to PD diagnosis. The results are equal or better than manual evaluation by an experienced sonographer. Also was tested ncl. raphe structure. Only 3 or 4 % percent of patients were detected incorrectly from diseased and non-diseased cases. All results have been also published in many IEEE journals with close collaboration with Prof. MUDr. David Školoudík, Ph.D., FESO as an experienced sonographer at the highest level of erudition in neurosonology profession.

Future work will be focused on software improvement and adding other ROI, especially to use this software to detection of atherosclerotic plaques. We want to detect atherosclerotic plaques inside the main cerebral arteries as the prevention of atherosclerosis and ischemic stroke. At first we must find appropriate characteristics how to evaluate level risk of atherosclerosis by diagnostic ultrasound. Nowadays the risk of atherosclerosis is judged only according to level of stenosis. Also we must investigate other characteristics which can be useful to evaluation of level risk of the plaques, e.g. heterogeneous/homogenous plaque, shape, size etc.

References