A new software for analysis of ultrasound B-images to detect kidney tumors for early diagnostics*

Jiří Blahuta[1,2,*,†], Tomáš Soukup[2,†], Jiří Martinů[1,†] and Michael Kuča[1,†]

[1]*Institute of Computer Science, Faculty of Philosophy and Science in Opava, Bezručovo náměstí 1150/13, 74601 Opava, Czech Republic*

[2]*Faculty of Medicine, University of Ostrava, Syllabova 19, 70300 Ostrava-Vítkovice, Czech Republic*

Abstract

The authors developed a new stand-alone software for ultrasound B-images analysis. Primary goal of this software is to detect kidney tumors from US B-MODE images. The application has been programmed in C# programming language using Unity engine. The idea of this software is based on our previous software in MATLAB but many functions are improved and also new functionalities are added. Also, this new version is faster and better from UX point of view. We can work with many bitmap graphic formats and also with DICOM files which are used a standard in medicine. Currently we are testing all functionalities for future clinical study. The program can also be used for quick analysis on a mobile platforms.

Keywords

ultrasound B-images, C# software, kidney tumors detection, kidney ultrasound imaging

1. Introduction to software at a glance

Early diagnosis of kidney tumors is very important goal in nephrology. Thanks to modern medical imaging methods, this diagnostics should be faster and more accurate. One of them is diagnostic ultrasound. Diagnostic ultrasound is one of methods which are used in this field. Our paper is focused on B-MODE ultrasound imaging, one of many ultrasound imaging modes (A-MODE, B-MODE, M-MODE, etc.), see Online Resources at the end. Ultrasound examination is fast and non-invasive for patients and for doctors provides a reliable solution to analyze the image to decide on the next steps. Therefore, we have developed a software tool which can be an important assistant in ultrasound images analysis in this field. In this paper, we work only with B-MODE images. It is based on echogenicity level displayed as intensity level in grayscale in the range from 0 to 255. According to echogenicity level there are hyperechogenic (very light), hypoechogenic (gray) and anechogenic (black) tissues and structures. For example the air is anechogenic and soft tissues are echogenic. The Fig. 1 demonstrates different echogenicity on B-MODE image (a section of ultrasound TCS B-image with brain structures is displayed in this example).

This software has been developed based on previous version. This previous version has been created using MATLAB and many technical and clinical papers have been published. The core of the functionality is based on echogenicity level analysis inside a predefined Region of Interest area (ROI). Initially, the software has been used to detect Parkinson's Disease based on echogenicity level on substantia nigra structure in cooperation with an erudite neurosonologist. He has defined the principle and the goal of the algorithm in general. In 2014, the first clinical paper was published so that this software is really usable in clinical practice. [1]. In this study has been proved, that the principle is highly reproducible.

ITAT Conference, Workshop on Natural Computing, 2026, Biele Karpaty, Slovakia

*You can use this document as the template for preparing your publication. We recommend using the latest version of the ceurart style.

*Corresponding author.

†These authors contributed equally.

jiri.blahuta@fpf.slu.cz (J. Blahuta); tsoukup@centrum.cz (T. Soukup); jiri.martinu@fpf.slu.cz (J. Martinů); kuc0168@slu.cz (M. Kuča)

https://www.slu.cz/fpf/en (J. Blahuta); https://lf.osu.eu (T. Soukup); https://www.slu.cz/fpf/en (J. Martinů); https://www.slu.cz/fpf/en (M. Kuča)



© 2026 Copyright for this paper by its authors. Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

CEUR Workshop Proceedings ceur-ws.org ISSN 1613-0073

published 2026-11-09

CEUR-WS.org/Vol-4323/paper24.pdf

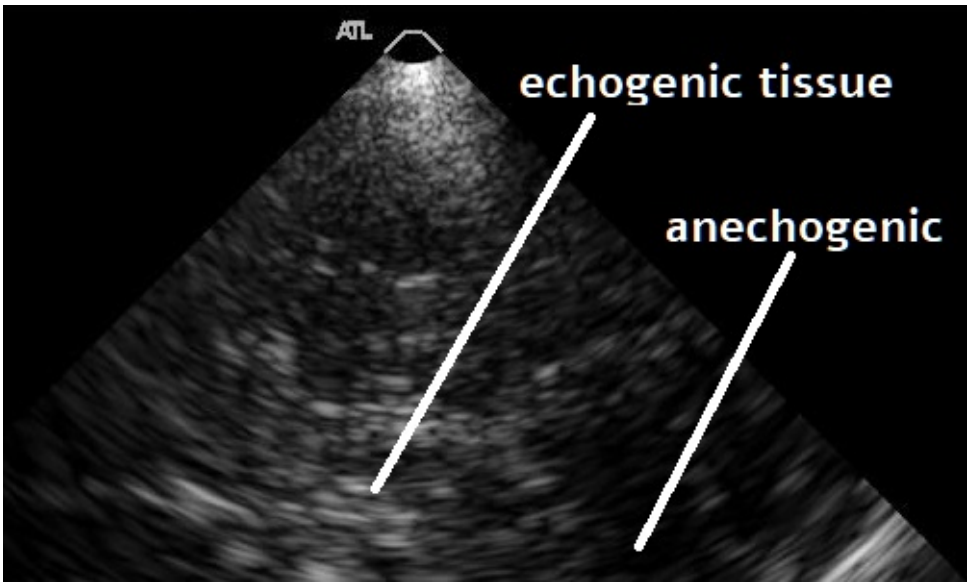


Figure 1: Different echogenicity levels in B-MODE imaging

Later, other brain structures have been tested and some new ROI areas added, e.g. free-hand ROI. We also tested the software for atherosclerotic plaques progression with free-hand ROI but the results were not usable in clinical research [2].

This old version needs MATLAB Compiler Runtime and Java Runtime Environment to execute. It could be problematic for someone who is non-experienced in IT.

1.1. Different cases of using our software in B-MODE image analysis

The core idea of B-MODE images analysis is based on computing Echo-Index value which describes echogenicity level. The Echo-Index is computed inside the selected ROI as we mentioned.

The part of the algorithm was used also for computing Black-White Ratio inside medial temporal lobe (MTL) to analyse MTL atrophy; there we used only the part of the algorithm without computing Echo-Index, for details see [3]. MTL atrophy is one of important markers visible in B-image for Alzheimer Disease detection.

Later we have also used an experimental neural network for automatic positioning of the ROI for SN and later also using convolutional neural network with Active Contour algorithm for segmentation of the atherosclerotic plaques [4].

So, the application has many options to use for different ultrasound B-images, not only for brain structures. Also, we have tried use the algorithm for for MRI images to determine whether Echo-Index can be used not only for US B-images. This study has been presented in ITAT conference in 2021 [5].

The last study from 2022 was focused on using the software for thyroid gland tumors. It was an experimental blind study [6].

1.2. Principle of the Echo-Index computing

The Echo-Index is our created value to describe echogenicity level in selected ROI. The principle is based on binary thresholding. In the ROI, the thresholding is used to compute remaining area.

The principle of the algorithm is based on binary thresholding in a selectable ROI. In US B-image, each pixel has an intensity value $H \in \langle 0; 255 \rangle$. Thus, the processing is based on thresholding for each H value and computing the remaining area after each thresholding step. Finally, all computed areas are summated and divided by 100 to obtain echogenicity index, called Echo-Index in our study.

In the software, to obtain Echo-Index, there are the following steps:

1. Loading an input image
2. Select a window in which the examined ROI is visible
3. Select a predefined ROI or draw a free-hand shape
4. Inside the ROI the area A_T is computed according to the threshold T:
   a) The area is computed as the number of remaining pixels after binary thresholding
   b) For each threshold T in the range of 0 to 255. The number of pixels is computed and finally is converted into real mm^2 according to displayed scale, i.e. the window size in step 2

This is basic core algorithm designed originally for substantia nigra echogenity grade analysis using binary thresholding principle.

Let H is the brightness value of a pixel and T to be the threshold then A_T is the computed area for each threshold T in the range of $0 \leq T \leq 255$. The sum *SUMAREA* is computed as

$$SUMAREA = \sum_{T=0}^{255} A_T \tag{1}$$

and this number is divided by 100 to obtain Echo-Index value

$$Echo - Index = \frac{SUMAREA}{100} \tag{2}$$

Due to the principle of binary thresholding, for lower echogenicity grade, the Echo-Index should be lower and for higher echogenicity the Echo-Index should be higher. This is an assumption by the principle of binary thresholding. Thus, in the case of low echogenicity, for low T threshold the computed area should be very low and vice versa. In consequence of this principle, the sum for low echogenicity should be low and for high echogenic ROI the sum should be higher.

In the following Fig. 2 you can see different Echo-Index for lower and higher echogenicity grade inside the ROI (Renis shape).

2. New version of the software

Our new software is developed in the C# programming language using Unity Engine. Although this engine has been primarily designed for gaming development (computer and mobile), but also provides highly powerful options to develop non-game software in which the computer graphics has a key role. Medical imaging and processing is one of them.

The core functionality of the software stays the same but there are many new functions, not only for better UX usability. To run it, you do not need any extra libraries, components, compilers installed. Furthermore, the application is executable as-is and no installation is required, so it is simply shareable as a ZIP file. It runs on Windows 10 and 11 and also on the Android mobile platform (Android 11 and newer).

The following figure shows the GUI of the application with selected 'Renis' elliptical ROI for kidneys analysis.

The workflow is as follows:

1. load an image (bitmap or DICOM)
2. select the window from the image by selecting two points
3. select an appropriate ROI
4. you can drag the ROI and the Echo-Index is automatically calculated

All computed values can be simply exported into a CSV file with one click.

The following Fig. 3 shows the process of selecting the window from the image (axis)

After running the application we can see we can see a blank white window with default scale 5×5 mm but after window selection and click the ROI, the axes scale is automatically resized according to the window size, like 10×10 mm, see Fig. 4.

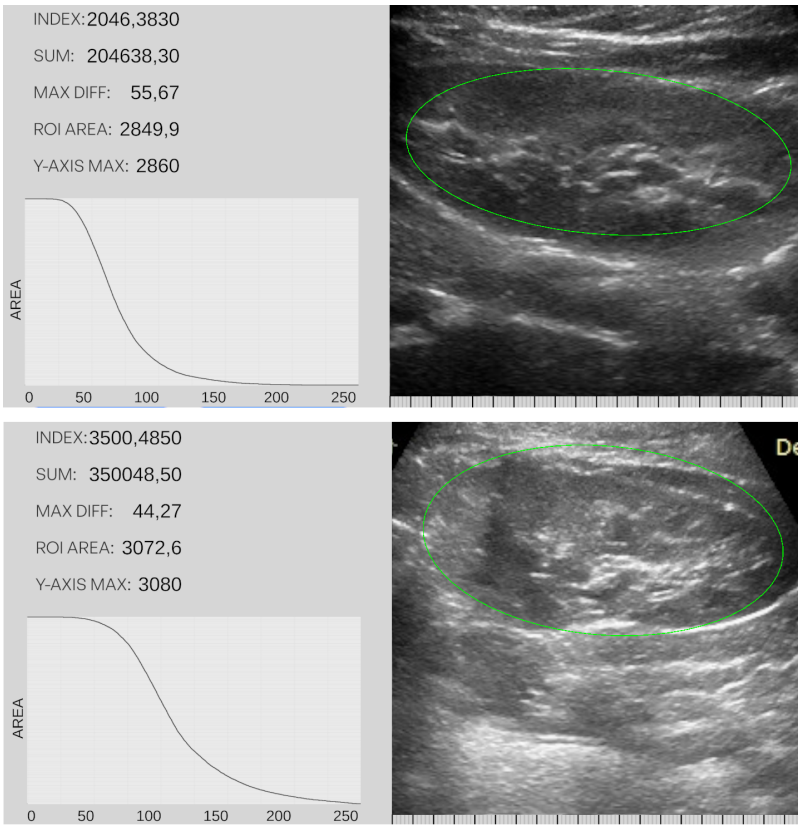


Figure 2: Lower Echo-Index and higher Echo-Index for different echocgenicity grade in US B-image

2.1. New and improved features

As we mentioned, the new version has some new and/or improved features in comparison with the old original version. There are some:

- new ROI options (buttons) designed for kidneys
- live Echo-Index computing when dragging the ROI
- all computed values and graphic visualization visible together (no separated windows)
- option to save the position and shape of the ROI for future using (only for 'Renis' ROI)

There are buttons to set the position and shape the ROI (rake angle, enlarge/decrease horizontally or vertically), see Fig. 5.

This function is available only for 'Renis' ROI because another have fixed settings and a free hand ROI can have any shape. The settings of Renis is stored in a TXT file in data folder with EXE file. This file contains coordinates of the the ROI settings, like $13.1419; 8.820948; -45; 36.947; 112.1376$. So, we can use the same settings as default until we change it.

As we mentioned, we can also use free-hand ROI for the kidneys defined by manually drawing the shape. The main advantage of this is to draw an exact border of the examined kidney but the disadvantage is different area of each one. The Fig. 6 shows the border using free-hand ROI drawing.

When you draw, the shape is automatically closed when click.

2.2. Running on Windows and Android

Unity Engine provides development for Windows and Android in one project together. There is the option to compile the project as EXE file for Windows and also as APK package for Android application. So, our software runs on Windows and on Android together.

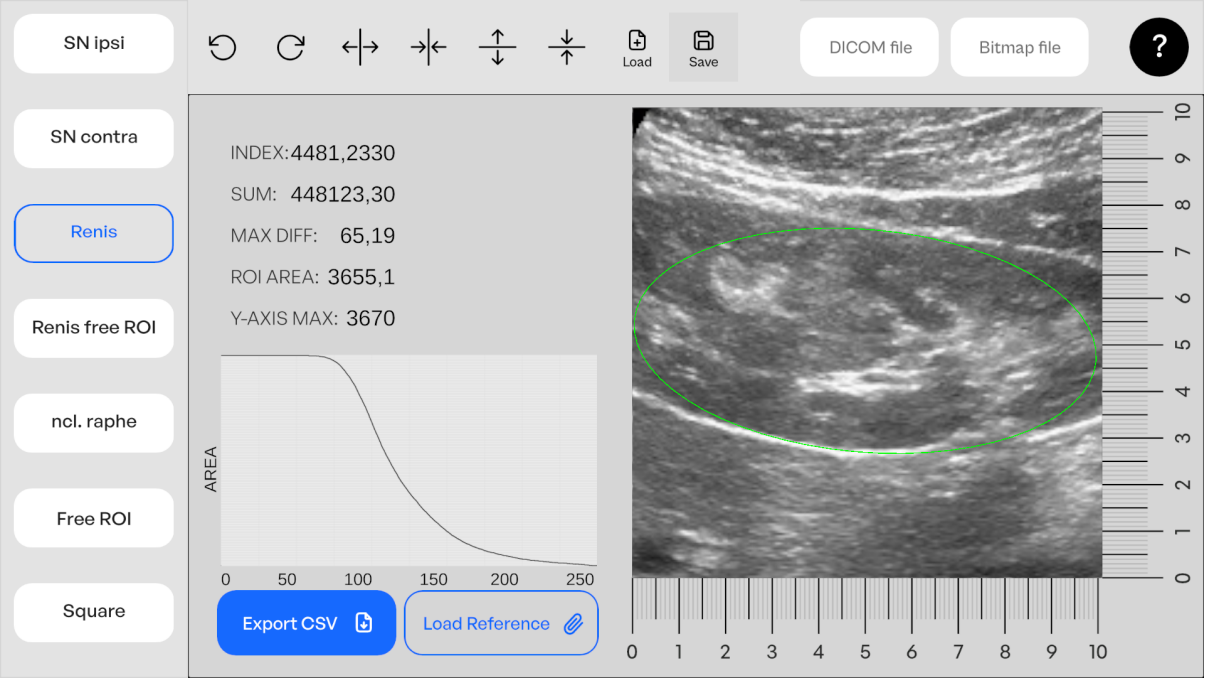


Figure 3: GUI off the application with selected ROI for kidney B-image

Owing to this option, the development must be adapted for both platforms. There is not only UX front-end (buttons size, etc.) but all functions must work for clickable environment on desktop (Windows) and for touch displays on mobile platform. For this, Unity Engine is a perfect tool. Working on touch display, especially when free-hand ROI is used, may be less precise in comparison with mouse or touchpad.

One specific matter on touch display is double-click. While with mouse or touchpad double-click is used for action confirmation (like to confirm selected window; Fig. 2), it is complicated on touch display. So we have designed our own algorithm 'tolerated double-click' to avoid recognizing as a new click and dragging. The principle is based on settings the time (0.4 s) when the second click is recognized as a double-click and no dragging. This implementation improved UX usability on touch display.

Also desktop version provides larger screen. All these aspects must be taken into consideration. Finally, we have tested desktop clickable working and also on touch display to prove that functionality is well done. Furthermore, the important aspect is that GUI on Windows and Android looks equal, there is no disunity. The application must provides the same functionality on both platforms.

3. Testing the software on real data

Currently, we are testing the software on real US data from technical point of view to prove the functionality.

The software is still under development but all features working correctly in general. We loaded bitmap files with different resolution, DICOM files, define a window size, using all ROI, options to set the shape and save it.

In 2025, we published the paper [7] which focuses on experimentally observing Echo-Index for left and right kidney using the old version of the software. In this study we observed changing Echo-Index and also comparison the results with scintigraphy. Echogenicity results were then compared with relative renal function determined using nuclear medicine methods. Results using the B-MODE Assist system demonstrated the sensitivity of 57-100 % and the specificity of 70-100 % in predicting renal pathological findings using ultrasound echogenicity compared with nuclear medicine methods. It was

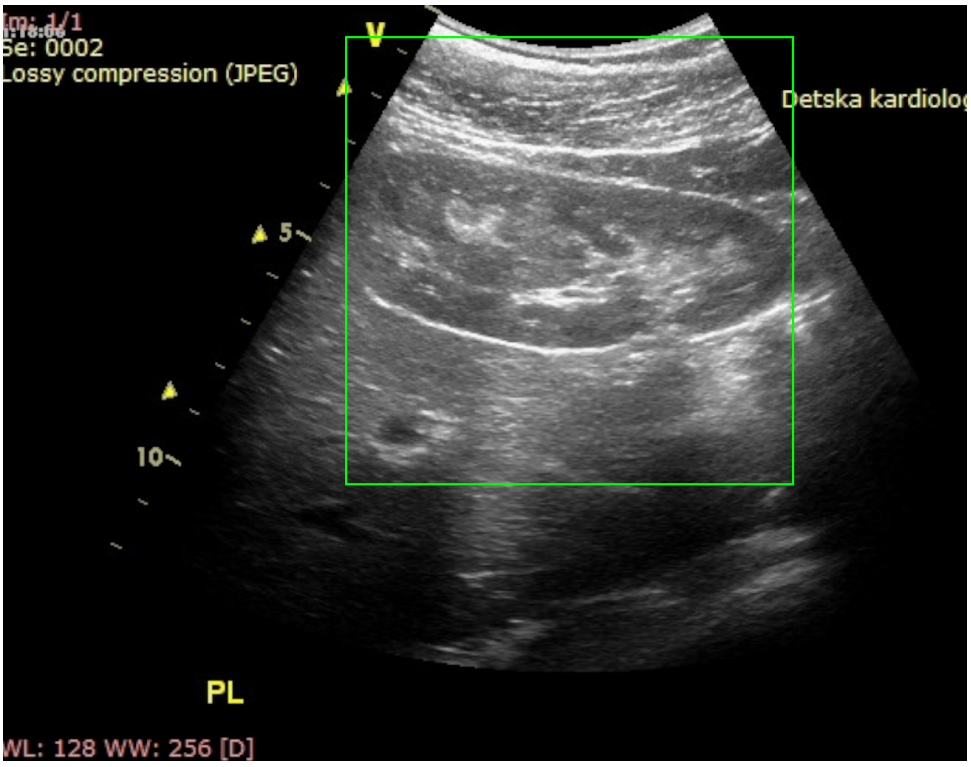


Figure 4: Select window (10×10 mm) from the image

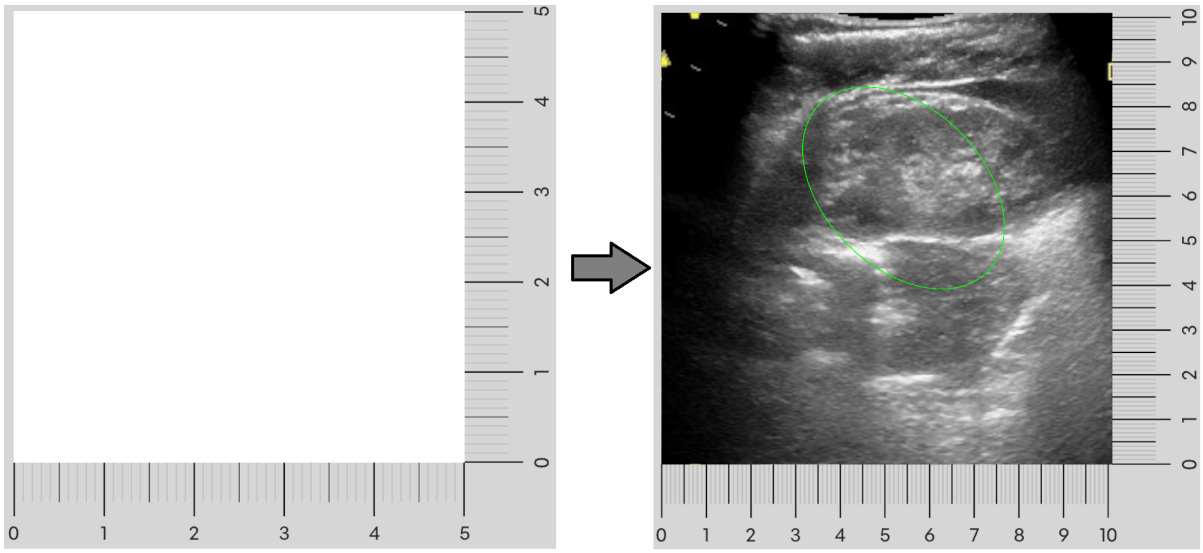


Figure 5: Automatic rescaling the axes according to window size

an experimental study with examined total of 17 children patients.

For a clinical study there are two barriers:

- we have no experience how to precisely select ROI (borders of the kidney)
- we do not recognize kidneys with or without tumor; we must cooperate with an experienced nephrologist to observe if the Echo-Index is different with/without tumor

However, the clinical study is one of the main goals in future work.

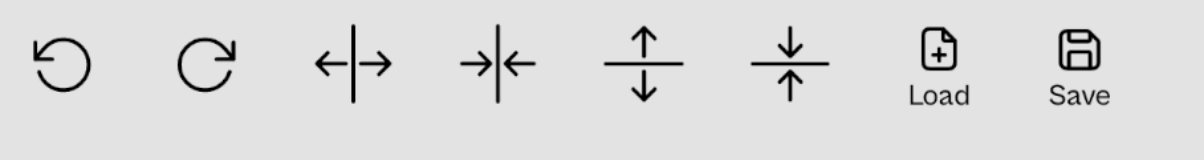


Figure 6: Buttons to set the ROI shape and save it

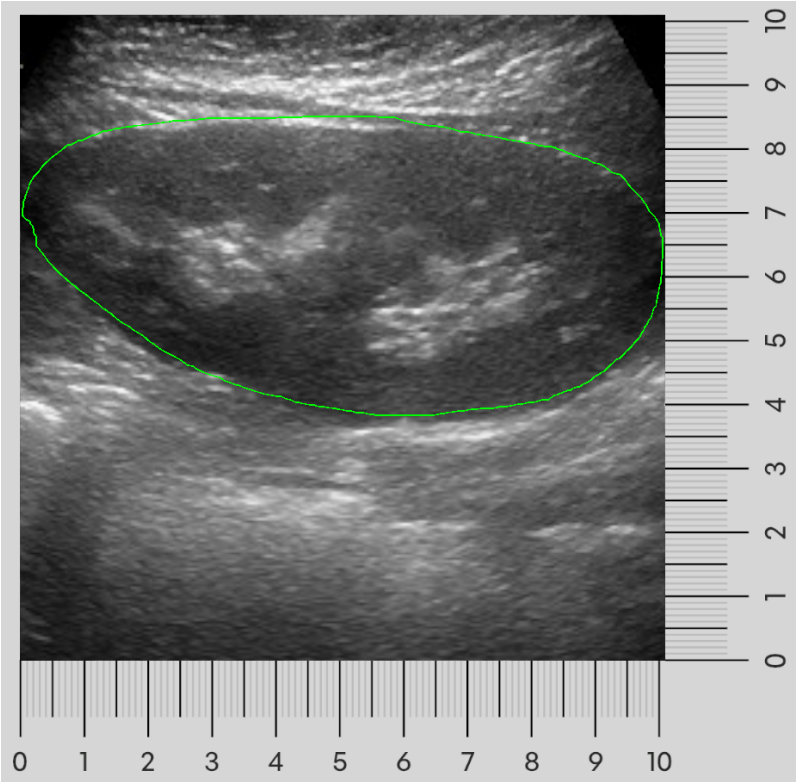


Figure 7: Free-hand 'Renis' ROI defined by manual drawing the border

4. Related work

Currently exist some software tools and methods focused on AI-based automatic boundary detection of the kidneys, for example [8], [9].

The first paper [8] is a systematic review of existing studies focused on image segmentation and diagnosis and prediction of renal diseases using AI-based implementation like convolutional neural nets (CNN) SVM machine learning, fuzzy neural nets, advanced texture analysis methods, etc. In major studies input data are 2D images.

The second study introduces a automated diagnosis system (ADS) to identify kidney disease from 2D US B-images. There is a new created neural network type named Ultrasound Network (US-Net).

Our solution brings easy-to-use software based on relatively simple algorithm with Echo-Index value to observe changing echogenicity grade level. This work has been successful in clinical studies in previous years in neurology. The principle can be used for different US B-images in various medical fields.

5. Conclusions and future work

The new version of the software is fast and stable, really better than older first version in MATLAB. We have tested all available features and no issues detected. In general, we have three main aims for the future work.

The application can be extended with new functions, ROIs, etc.

Secondly, some AI components should be developed, such as automatically finding an appropriate free-hand ROI for kidneys and/or finding an universal 'Renis' ROI which can be used for > 90 % of cases.

And the last part of the future work should be focused on clinical use of the application to detection of kidney tumors. This work is interdisciplinary; it is an interconnection of modern radiology and software development using AI in image processing. Thus, we must co-operate with an experienced expert in nephrology who can classify the images with and without kidney tumor. This classification could be also an approach for AI to automatic classification. The goal of this part is to determine whether Echo-Index differs significantly between tumorous and normal kidneys. It is an extension of the paper [7].

Declaration on Generative AI

The authors have not employed any Generative AI tools.

References

[1] BLAHUTA, J., BÁRTOVÁ, P., JELÍNKOVÁ, M., ČERMÁK, P., HERZIG, R., ŠKOLOUDÍK, D. *A new program for highly reproducible automatic evaluation of the substantia nigra from transcranial sonographic images.* Biomedical Papers, 2014, 158(4), pp. 621 - 627. DOI:10.5507/bp.2013.029.

[2] BLAHUTA, J., SOUKUP, T. MARTINŮ, J. *An Expert System Based on Using Artificial Neural Network and Region-Based Image Processing to Recognition Substantia Nigra and Atherosclerotic Plaques in B-Images: A Prospective Study.* In: Rojas I., Joya G., Catala A. (Eds.) Advances in Computational Intelligence. IWANN 2017. Lecture Notes in Computer Science, Vol. 10305, pp. 236 – 245. Springer, Cham. DOI: 10.1007/978-3-319-59153-7_21.

[3] ŠKOLOUDÍK, D., KRULOVÁ, P., KISVETROVÁ, H., HERZIG, R., BLAHUTA, J., *Transcranial sonography of the medial temporal lobe in Alzheimer's disease patients.* [Transkraniální sonografie mediotemporálního laloku u pacientů s Alzheimerovou demencí]. Ceska a Slovenska Neurologie a Neurochirurgie, 2020, 83(2), 189-193. DOI:10.14735/amcsnn2020189.

[4] BLAHUTA, J., SOUKUP, T., SOSÍK, P. *Approach to automatic segmentation of atherosclerotic plaque in B-images using active contour algorithm adapted by convolutional neural network to echogenicity index computation.* Paper presented at the CEUR Workshop Proceedings, 2020, Vol. 2718, pp. 223 - 229. ISSN: 1613-0073.

[5] BLAHUTA, J., SOUKUP, T. *Brightness Levels in MRI Should Correspond With Echogenicity Grade in Ultrasound B-MODE Images: A Pilot Study of Reproducibility Using ROI-based Measurement Between Two Blind Observers.* Paper presented at the CEUR Workshop Proceedings, 2021, Vol. 2962, pp. 183 - 187. ISSN: 1613-0073.

[6] BLAHUTA, J., SOUKUP, T., LAVRINČÍK, J., PAVLÍK, L., REPASKÁ, Z. *Measurable Difference Between Malignant and Benign Tumor of the Thyroid Gland Recognizable Using Echogenicity Index in Ultrasound B-MODE Imaging: An Experimental Blind Study.* Bioinformatics and Biomedical Engineering: 9th International Work-Conference, IWBBIO 2022, pp. 283 - 296. ISBN: 978-3-031-07703-6, DOI: 10.1007/978-3-031-07704-3_23.

[7] BLAHUTA, J., PAVLÍK, L., SOUKUP, T., KOZEL, J. *The pilot study of B-MODE image analysis of kidney diseases.* SGEM 2025, 25th International Multidisciplinary Scentific GeoConference, conference proceedings, BULGARIA, DOI: 10.5593/sgem2025/2.1/s07.08.

[8] LIANG, X., DU, M., CHEN, Z. *Artificial intelligence-aided ultrasound in renal diseases: a systematic review.* Quantitative imaging in medicine and surgery, 13(6), 2023, pp. 3988–4001. DOI: 10.21037/qims-22-1428.

[9] SUDHARSON, P., KOKIL, P. Automated diagnosis tool for clinical ultrasound image analysis in kidney disease identification. Biomedical Signal Processing and Control, Volume 111, 2026, 108345, ISSN: 1746-8094, DOI:10.1016/j.bspc.2025.108345.

6. Online Resources

- Unity Engine
- DICOM
- Ultrasound Modes Explained