

Brain Tumour Detection

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Abstract Cancers are the most serious problems of the medicine. Adequate treatment of early diagnosed patient gives the patient possibility of healing, to improve the quality of life and to return to normal life. Most of the tumors are characterized by the presence of one or several more or less specific markers. By processing the presence of multiple markers - although with a lower sensitivity and specificity - we get an overall picture of the body organs. The aim of this project is to monitor, evaluate and process results of magnetic resonance imaging. The results are provided to doctors in the form of graphs, 2D and 3D models and tables. This application also brings the possibility of processing error values of the measurements of markers.

Keywords: brain, tumour, detection, model, XNA, error processing, markers, magnetic resonance imaging (MRI)

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1. Introduction

Research in any area of life is important, the human society is progressing steadily. Application of new knowledge and technical innovations into standard medical practice creates new diagnostic and therapeutic methods, which can affect the life of the patient.

Cancer is one of the most serious problems, research priority in the medicine. It affects primarily the patient's life, but also its surroundings and society. The name of the medically oriented engineering project is Hospital information system at the Faculty of Management Science and Informatics, University of Žilina (Slovakia) led by prof. Ing. Karol Matiaško, PhD. The basis of the project is to cooperate with the Faculty Hospital in Martin (Slovakia), which defines specifications of the system, the practical requirements of the users of the information system are transformed into software.

The aim of this project is to detect, locate, and view a brain tumor, its location and properties. Doctors for whom the project is intended interpret the results of magnetic resonance imaging (MRI). All anomalies based on the measurement are colourly displayed and modeled. Our application offers a variety of display modes - 3D model of the head, a 2D model sections and charts. It also gives the possibility of calculating undefined, respectively incorrectly measured parts of the brain. Methodology could be used prospectively in the diagnosis of other diseases of the brain.

2. Analysis

Engineering project - Hospital information system was established in 2009 as the beginning of a long-term cooperation of the Faculty of Management Science and

Informatics, University of Žilina and University Hospital in Martin. The aim of this project is to develop and improve the software according to their requirements and feedback. This project is thus directly related to practice. In the initial phase, a database for ambulance modular structure was created to form a unified communications, data processing and storage. In September 2010, the project expanded – process and detect brain tumors. The first task was recognition and visualization of brain anomalies based on DICOM files. However, the output of magnetic resonance also contains the values of presence of the markers (marker described later), but also incorrectly measured values, which should be removed, respectively replaced by valid value. The results are thereby provided to medical workers in a comprehensible form, in the form of graphs, 2D and 3D models. Sections of the brain in the form of images does not contain as much information as markers measurements. However, brain slices provide us better opportunities for visualization.

The main reason for the development was the fact that values had been processed "manually" without the possibility of creating new markers, visualization and evaluation.

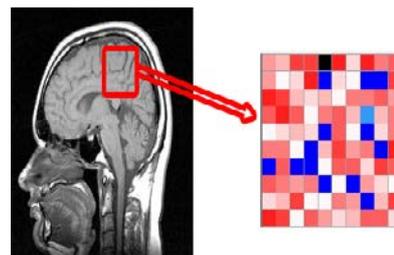


Figure 1. 2D model + image

This project requires some insight into medical issues, a basic overview of the issue of the brain tumors and imaging methods used in the diagnosis [5].

3. Tumours

Intracranial tumours are a diverse group of tumours that differ in localization, symptoms, histological composition and the occurrence of some species depend on age. The most common symptoms are limb movement disorder, numbness, vision, speech or mental changes. Another group of symptoms are resulted from local brain tissue irritation manifested as different types of seizures. Syndrome of increased intracranial pressure is referred to a set of symptoms, which include mainly headache, vomiting and visual disturbances [9,10].

Based on histology, intracranial tumors can be divided into tumors based on brain cells, the brain nerves, based on blood cells, metastatic tumours (e.g. spread by blood cells from the locality of the primary tumor - the most common cancer of the colon, lung, breast). Division of tumors to malignant and benign has relatively less importance than in the tumors of other organs; the brain is tightly enclosed; also slow-growing benign tumor causes a serious problem [9,10].

The most common way of treating brain tumors is surgery that also provides samples for histological examination. Sometimes the tumor cannot be cured, partial removal of it may alleviate symptoms of brain damage.

Another method of treatment is radiotherapy - X-ray irradiation of the tumor or a stream of charged particles. Using external radiation, the rays of the irradiation device outside the patient's body are directed to the tumor. In stereotactic surgery, the radiation is directed to the tumour location (based on CT or MRI); thus, it partially protects the surrounding tissue. The method of internal radiation therapy is brachytherapy, in which a radioactive substance in the form of grains is placed into tumor.

The third treatment method is chemotherapy, which is used to destroy cancer cells using medicines - cytostatics. The aim of chemotherapy is to destroy the tumor remains after surgery. Prognosis of patients with intracranial tumors depends on many factors - the type, location and histologic composition of the tumor, patient's age, general condition and comorbidities, the treatment options and response to the treatment [9,10].

4. Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging is the diagnostic method used to create two-dimensional and three-dimensional images of organs in the human body. The method has been used in health care since 1980, it is a unique and increasingly used mostly for its ability to create high-quality images without the use of radiation.

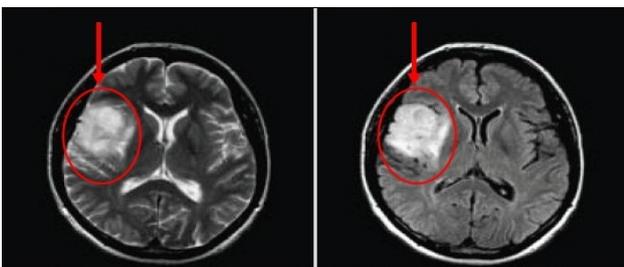


Figure 2. Brain tumour

Magnetic resonance imaging is based on the principle of measuring changes in the magnetic moments of nuclei of elements with odd atomic number placed in a strong static magnetic field after application of radiofrequency pulses. Due to the rotation atom nuclei around axes (spin), the core magnetic field (magnetic moment) is formed. Hydrogen atom contains one proton in the nucleus and in the tissues as abundant. If the examined tissue is put in a strong magnetic field, layout proton spins in one direction. In practice, there are two opposite directions, one of them predominates - so the resulting magnetic moment is therefore in one direction. In this state, the magnetic moment of protons takes place two types of movements - both rotates around axes (spin) while moving around an imaginary cone shell, which is called precession. If the radiofrequency pulse (electromagnetic waves in the radio band short wave) is applied in the tissue with a frequency consistent with the proton precession frequency, resonance occurs according to the principle of magnetic moments deflection from the original direction by a certain angle and also synchronizes all proton precession. After the pulse occurs, everything returns to its original state. Time for that is known as relaxation time.

The time required to return biased magnetic moment is known as T1 relaxation time, "get out of sync" precession is known as T2 relaxation time. Both depend primarily on the composition of the material studied in the vicinity of protons. Signal, which is obtained after a series of different radio pulses, has the same character - it is electromagnetic wave that can be registered by receiving coils (basically antennas) and measures its size. A series of pulses required to obtain a measurable signal is referred as a sequence. Proton resonance frequency depends on the intensity of the external magnetic field. If this field gradient coils with appropriate modifications, we can obtain information about the location from which the signal arrives.

The principle of MRI is based on the measurement of magnetic moments of nuclei of hydrogen atoms in the water and fats.

During the patient examination image layers are made using various types of sequences informing about the difference of relaxation times T1 and T2 (T1 or T2-weighted sequence) or the number of protons (weighted sequence by proton density). It is necessary to compare the signal strength of the same place in different types of sequences to get the complete information.

The examination takes 20-60 minutes demanding on the speed of particular device and the number of displayed sequences.

MRI is most often used in neuroradiology, to display diseases of the brain, spinal cord and spine. In addition, it can be used to diagnose musculoskeletal disorders; it can display all the components of bone and bone marrow by ligaments, tendons, muscles and cartilage. Increasingly, MRI is also used to view the organs in the abdomen, chest and neck. The advantage of MRI is more detailed view of soft structures, the ability to view in any plane, and the absence of radiation. MRI cannot be used for patients with pacemakers; implanted metallic materials in the body complicate scanning due to possibility of heating or displacement of implanted material [1,2,6].



Figure 3. MRI (Siemens Avanto)

5. Tumour Markers

Tumour marker is a substance, usually protein, the occurrence of which indicates the presence of cancer. This substance can be almost exclusively produced by the tumour cells, thus the healthy cells do not produce them, but the markers can also be part of the normal cells, the presence of which in abnormal quantity or time also indicates the tumour. In general, we can observe the presence of these markers either within the tissue, which can distinguish between normal and damaged tissue or in body fluids (e.g. serum, urine, cerebrospinal fluid), in which these substances are released from the tissues. We use the term marker for a substance that occurs directly in the tumour tissue for this purpose. Markers in this sense may be either protein, or cell surface proteins that are part of the cellular metabolism (such as enzymes, hormones). Most tumours are characterized by the presence of one or several more or less specific markers. An overall picture is captured by tracking the presence of multiple markers - although with a lower sensitivity and specificity.

Searching for cancer in the population by monitoring the presence of markers in the blood is not used, because the tests have a relatively high sensitivity but lower specificity. The importance of monitoring the presence of tumour markers on the contrary is essential for patients with proven presence of malignancy. It is important to know the values of markers in the blood and in the tumour tissue at the time of diagnosis.

Monitoring the presence of these markers is also important during the treatment. Decreasing values of markers indicate good treatment effect. If the values do not change or are rising, it indicates the resistance of the disease to a particular treatment. Monitoring the presence of markers is used after cancer treatment, too. If the values begin to rise, it means that the number of tumour cells in the body is again increasing, suggesting either the tumour reappearance or the extension of the tumour in the form of metastases. Accordingly, it may proceed with treatment as soon as possible [4,5].

6. Implementation

Project can be divided into three parts:

1. **Brain_tumour_detection**, which includes results processing of the magnetic resonance imaging, methods

for data processing, for removing incorrect values of the measurement and also models itself in the form of graphs, 2D model and models for progress monitoring over time.

2. **3D_visualization** - a module for creating a 3D model of the brain. Each layer represented a 3D model of the brain is in the form of 2D. The actual slice is displayed on the user's choice to show abnormalities that may indicate cancer or other potentially medically significant finding. Used "XNA Game Studio 4.0 Refresh" is based on hardware acceleration and is often used in games. It allows integration into most modern technologies (.NET Framework, Silverlight, WPF, ...) [8,11].

3. The last module connecting previous ones is **CommonClasses** containing classes needed to communicate with 3D visualization module.

7. Parameters and Attributes

Most important parameters and attributes of the application are:

Critical value - expresses the maximum value of the marker, which is still considered to be acceptable and is not considered as a potential anomaly.

Tolerance value - expresses the maximum acceptable difference between the different results of the CAT scan over the time. This value is used to monitor tumor growth (e.g. a comparison before and after the surgery).

Threshold value - expresses the maximum value of measurement error, which is still accepted by the user. If he wants to reduce the value of the error, it can calculate the new value of the error marker and surroundings.

Attributes *brain_cur_marker*, *brain_cur_cholin* store values of the selected marker and standard marker (choline) throughout the measured spectrum (head, brain). For each of these attributes, there is the same size and structure - data of the measurement error in that location. Measured values have often (especially at the edges of the investigation) high measurement error and therefore it is possible to replace them with new values, calculated from the neighborhood. If the value is changed, this information is also stored.

8. Data Normalization

Methods for carrying out standardization of values:

- Maximum normalization.
- Range normalization.

If marker value is negative, it must be transformed before the normalization into the positive axis, that means, to each value is added minimum value of the whole structure.

If the value exceeds the error limit (threshold value), you can try to calculate the new value, which would better reflect reality (the value of the error will be reduced).

New value is defined as the average of the surrounding cells, x_{ijk} expresses newly defined voxel value at position (i, j, k). The current value is not processed, because it is not considered credible.

$$x_{ijk} = \left(\sum_{a=-1}^1 \sum_{b=-1}^1 \sum_{c=-1}^1 x_{(i+a)(j+b)(k+c)} \right) - x_{ijk} \quad (1)$$

Standard input application file is CSV (Comma Separated Value) file consisting of measured markers of the patient. Sample files of volunteers and test data were provided by Faculty Hospital in Martin. Each file contains 58 columns. The first column contains the ID, the other three columns define the position of the element in 3D space (x, y, z). The remaining 27 columns contain values of markers (Ala, Cho, Gln, Glu, Ins, Lac, ...). The measurement error is not uniform, thus error values (Ala_SD, Cho_SD, Gln_SD, Glu_SD, Ins_SD, Lac_SD, ...) for each marker position are also particularly stored - 27 columns.

ID	x	y	z	Ala	Ala_SD	Cho	Cho_SD
0	0	0	0	44,6508	9,8641	84,9545	11,1195
1	0	0	0	15,1078	32,4787	12,2794	20,9175
2	0	0	0	33,5510	7,2037	41,5312	11,8363
3	0	0	0	3,4207	12,3078	33,6234	4,1083
4	0	0	0	43,9448	33,9521	89,9960	25,2200
5	0	0	0	69,7599	19,4453	35,5144	2,9355
6	0	0	0	65,0320	9,5264	66,7199	6,6280
7	0	0	0	1,4384	16,5044	93,9893	7,2396
8	0	0	0	20,4445	44,6979	12,2822	32,6038
9	0	0	0	20,0698	35,1697	42,3146	37,8528
10	0	1	0	12,8794	24,9478	60,4904	18,3295
11	0	1	1	56,7193	36,6331	94,6579	27,8126
12	0	1	2	22,2727	49,8133	61,2960	14,1833
13	0	1	3	21,5970	23,6323	26,2960	7,7906
14	0	1	4	48,6578	12,4129	69,7851	6,2195
15	0	1	5	56,6798	49,8944	14,6887	18,9996
16	0	1	6	33,5048	14,3867	70,2553	33,8615
17	0	1	7	22,2317	27,0584	67,9899	1,6282
18	0	1	8	17,0507	40,1122	13,8136	12,7617
19	0	1	9	42,8158	22,2382	35,7041	4,2175
20	0	2	0	20,9364	7,6711	14,1621	16,7781
21	0	2	1	33,6249	12,7817	97,2595	24,2714
22	0	2	2	62,3389	37,6146	2,4034	23,1118
23	0	2	3	69,2409	14,4363	33,0675	35,2960

Figure 4. Input file

Figure 5. Creating marker form

The new value of the marker, which has been created using other markers is expressed in Equation 1 - set M contains all the markers in the definition (not only standard, but also made application). The definition must contain at least 1 marker. w_m is the weight of the marker definition, c is a constant added to the definition.

$$\left(\sum_{m \in M} w_m * m \right) + c = \text{new_marker} \quad (2)$$

The error value is calculated as a weighted average of the markers:

Some devices (such as MRI device used in a hospital in Martin - Siemens Symphony 1.5 Tesla - which provided us test data) store the proportion between the marker and the amount of choline in the cells. However, these values can be calculated (by the definition of a new marker) and therefore we do not use them. The following figure shows the structure of the input file:

All general markers, as well as user-created markers may be further processed mathematically and used to create additional markers. For this purpose, a new module created Marker, which can define new markers [4,7].

$$\frac{\left(\sum_{m \in M} w_m * m \right)}{|M|} = \text{error} \quad (3)$$

9. Error Data Processing

The data obtained from magnetic resonance imaging examination of the patient may not have the required quality at each voxel (voxel is a term referring a spatial element image. Unlike pixel covering a two-dimensional image, the term voxel is used in three-dimensional models,

it is displayed as a cube and has equivalent features as pixel). Even, in some locations, the marker value may be undefined, respectively incorrectly processed – it could indicate risk area (tumor). Therefore, these data must be "cleaned" and values with too high error must be removed. User sets the threshold value, which indicates the maximum error (in percentage), which can be accepted. All values with error greater than this threshold are considered to be unreliable (marked in blue, Figure 6).

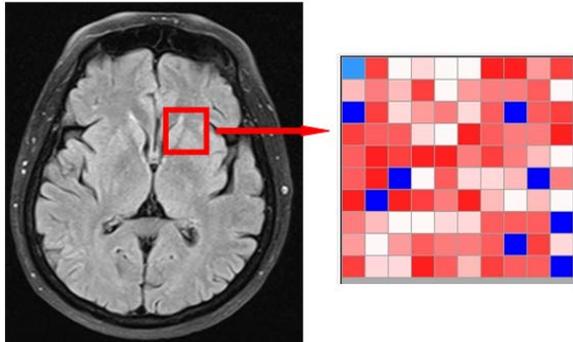


Figure 6. 2D model + slice of brain

But if the doctor needs to get the values in these areas, our application offers the possibility of calculating new values of the elements. Surroundings width 1 of "red" element we mean a set of voxel associated at least with one common edge in 3D space:

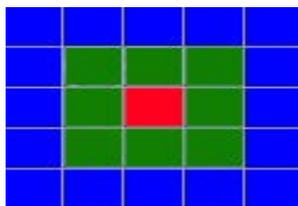


Figure 7. Surroundings

Thus, each element has 26 elements (or less) with a width = 1. The new value of the element is created by summing the values of all surrounded elements (specified by the width) and divided by the number of these elements. The new value of the element is considered correct only if the value of the error is reduced (value of the error is calculated the same way as the new value of the element). There is important to emphasize that it is not necessary to reduce the error value below the threshold. The main point is that the error value is diminished. Following formula

refers to the way of calculating the new value of voxels, sets A, B, C define the elements in the axes.

$$x_{ijk} = \frac{(\sum_{a=-1}^1 \sum_{b=-1}^1 \sum_{c=-1}^1 x_{(i+a)(j+b)(k+c)}) - x_{ijk}}{|A| * |B| * |C| - 1} \exists x_{(i+a)(j+b)(k+c)} \quad (4)$$

If the new value is defined by the wider surroundings, weights of the value elements is added to the formula (the closer element has the greater weight). $w_{(i+a)(j+b)(k+c)}$ expresses the weight of the element $x_{(i+a)(j+b)(k+c)}$ - the value of the element at the position $(i + a) (j + b) (a + c)$. (The weight of the element x_{ijk} is „0“, because it is considered to be untrustworthy).

$$x_{ijk} = \frac{\sum_{a \in A} \sum_{b \in B} \sum_{c \in C} x_{(i+a)(j+b)(k+c)} * w_{(i+a)(j+b)(k+c)}}{|A| * |B| * |C|} \exists x_{(i+a)(j+b)(k+c)} \quad (5)$$

Elements for processing can be selected manually from a table (datagrid), or all the elements according to the criteria are selected., The following figure shows the unprocessed data element - its position (position x, y, z), the current value and the error value with the corresponding color category:

x	y	z	Value	Error value	
1	1	1	0,059	0,286	
1	1	5	0,012	0,293	
1	1	6	0,464	0,441	
1	1	9	0,602	0,272	
1	1	10	0,338	0,299	
1	2	1	0,249	0,249	
1	2	2	0,211	0,499	
1	2	4	0,562	0,437	

Figure 8. Voxels before processing

After successful processing (successful processing means a reduction of the error value), the new values and info about processing are displayed:

x	y	z	Value before processing	Value after processing	Error value before processing	Error value after processing	
10	10	10	0,616	0,267	0,481	0,191	
10	10	8	0,241	0,255	0,311	0,226	
10	10	5	0,371	0,407	0,329	0,224	
10	10	4	0,586	0,317	0,47	0,228	
10	10	3	0,571	0,24	0,319	0,308	
10	10	2	0,279	0,204	0,484	0,332	
10	10	1	0,192	0,196	0,461	0,328	

Figure 9. Voxels after processing

The next figure shows the entire form for processing data errors of the measurement, the elements that have not been processed yet and also elements which error has been

reduced. The right side contains the navigation for threshold and sections setting. If it is necessary to see the original values, this option is also available.

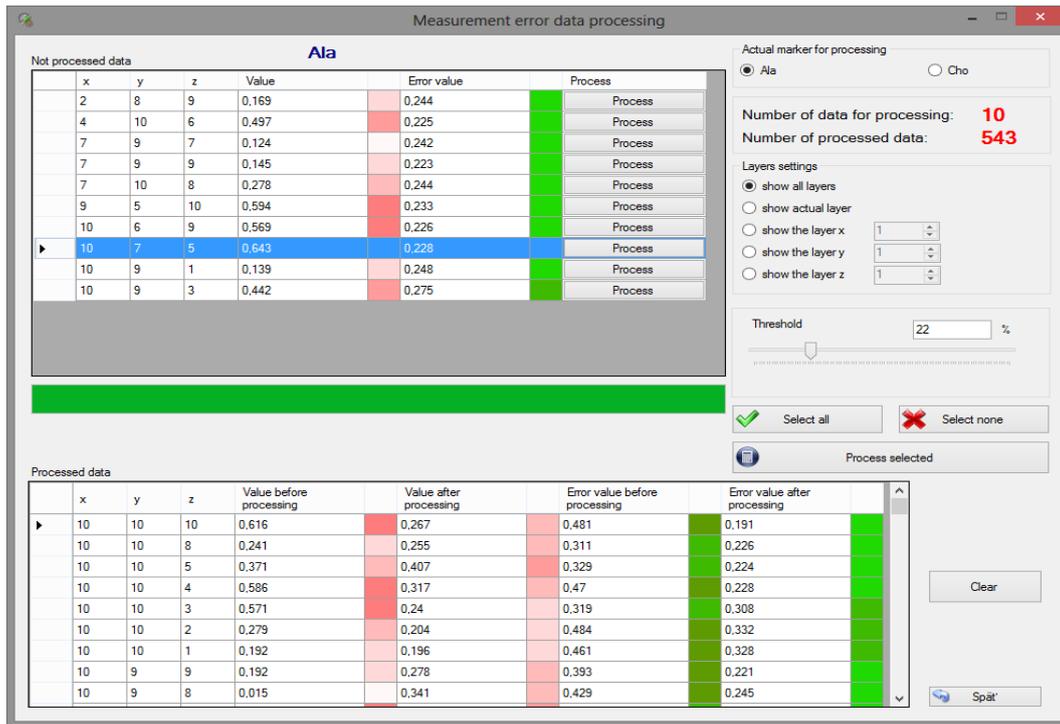


Figure 10. Measurement error data processing

10. Application Settings

The basic application requirements include universality - our developed application does not focus on just one particular device, but offers the possibility of setting parameters according to the type, quality and accuracy of the used apparatus, specifically, the settings of slice planes in all axes. Basic range of planes is <5; 200> allowing changes in "admin mode".

User can also set the values of precision (number of decimal places), as well as the default type of normalization, threshold and color charts and other parameters. The application offers three languages - English, German and Slovak.

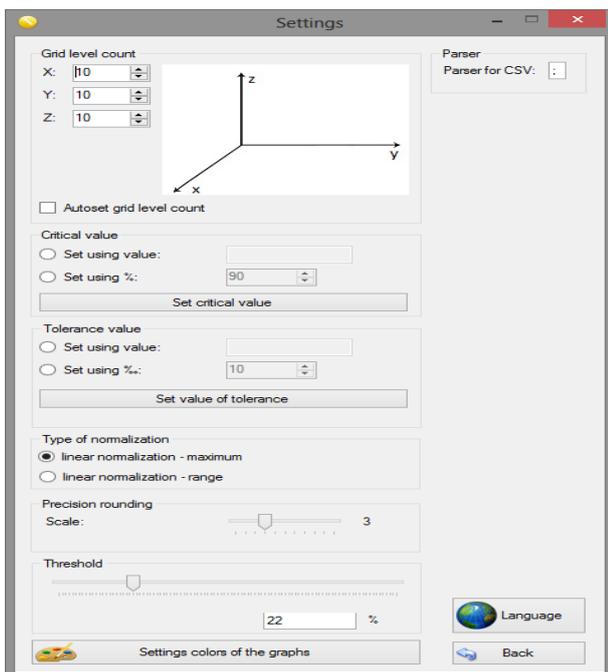


Figure 11. Settings form

11. Admin Mode

The "Admin" mode is designed for the application manager in a particular hospital. It allows setting the limits on the number of slices, the default critical value, the value of tolerance and separator and so on. The system administrator can also manage user-defined markers. The mode is password protected for security reasons, which is encrypted MD5 algorithm. Thus, the system stores only fingerprint of it.

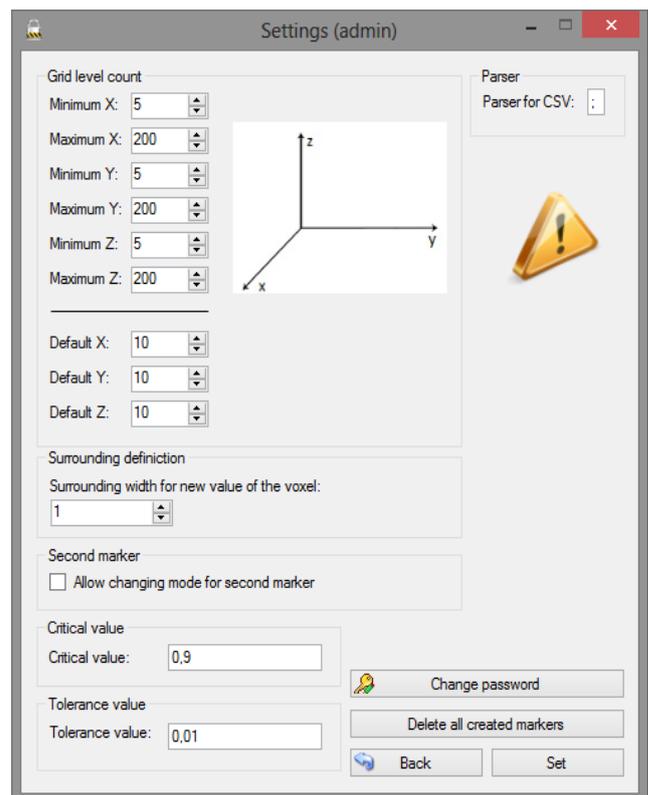


Figure 12. Admin form

12. Display Modes of the Application

Each voxel is characterized by its position in three-dimensional space, and the value of the marker errors. After loading the results of magnetic resonance imaging doctor is informed about the critical area and anomalies based on the parameters. If the anomaly is not found, the special sign is displayed characterizing the health of the patient (tumor (anomaly) was not found). Anomalies are characterized by elevated marker values at that position. The application works with 26-standard markers, covering a wide range of tumor detection. During the process of magnetic resonance imaging, the values are not obtained for all markers, Diagnostics is specialized in the expected types of tumors. In general, we can divide the value of each voxel into three groups:

- The voxel marker value is less than the critical value and the error is smaller than the threshold, it means anomaly has not been located there. This area can be excluded from further examination, it is not the risk of cancer in that place.

- The voxel marker value is greater than the critical value and the measurement error is less than the threshold. Anomalies are here located.

- Measurement error is greater than the threshold. In this case, we get voxel whose value exceeds the allowable error limit given threshold. These voxels are potentially at risk, they are recommended for further processing in order to reduce errors and calculate the value of a more accurate value of the marker.

13. Graph Module

Graphs module illustrates the value of the third axis in the form of a graph after selecting two section axes. The graph displays the values of currently set marker and choline (standard marker), but only those, that have values less than the threshold value. A frequent requirement is to compare the values of these two markers in each location. It is therefore possible to portray both charts together and monitor the values of both in one place.

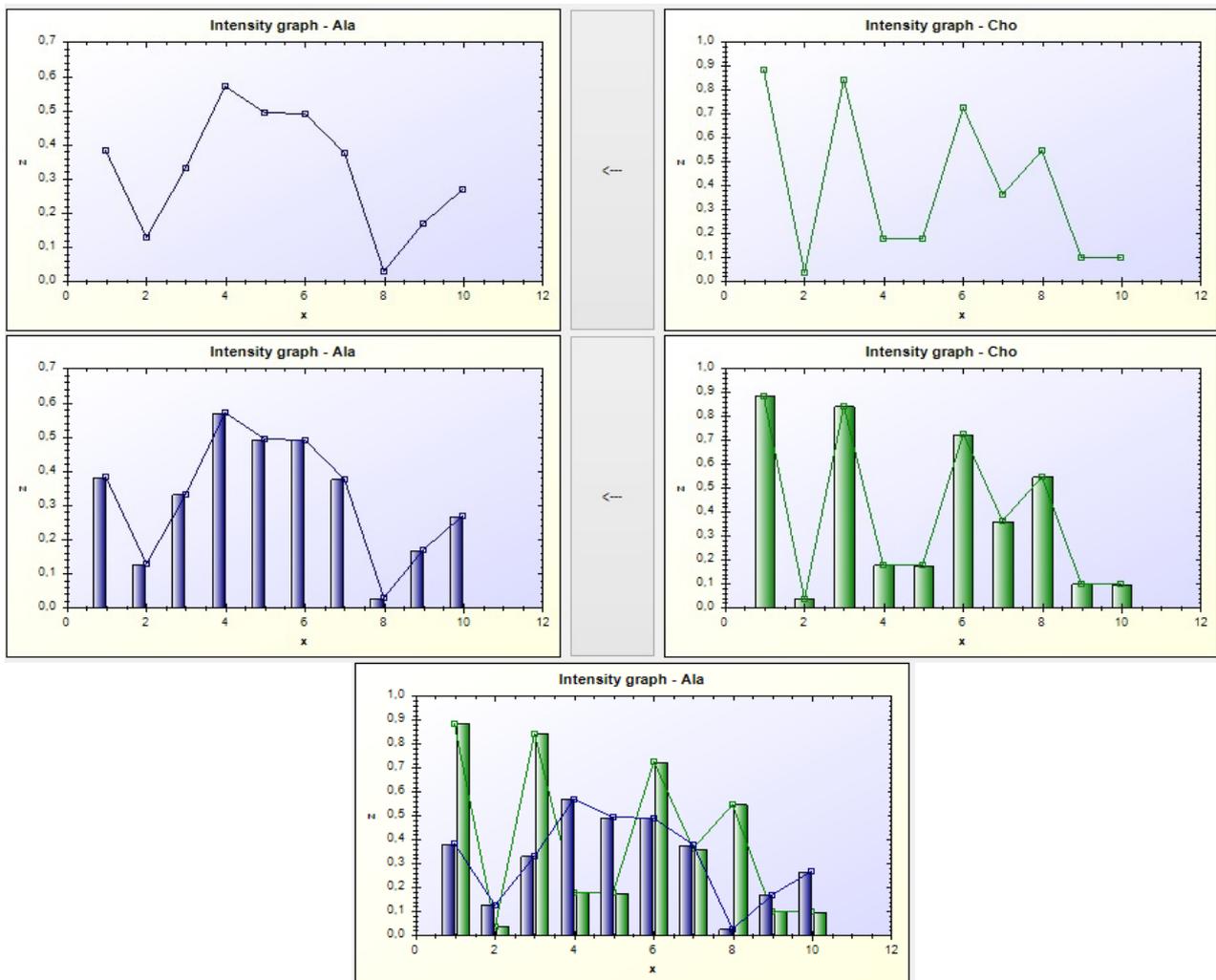


Figure 13. Graphs

14. 2D Model

2D model consists of four basic parts:

- Model of the selected marker values (in the selected section, location).

- Selected measurement error marker model.
- Model of the second marker – mostly chosen is „cholin“
- Measurement error of the second marker.

All these values are in separate DataGrids and colorly modelled.

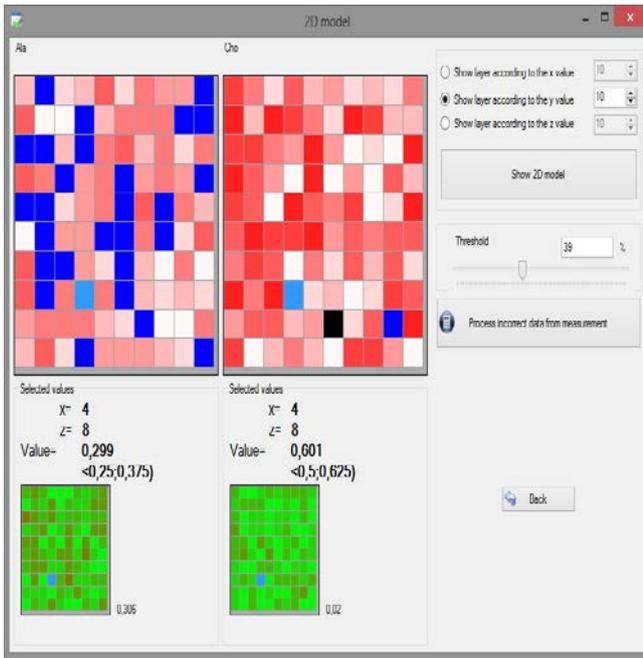


Figure 14. 2D model form

If the doctor needs the values in unmeasured locations, more accurate value, error handling module can be used to reduce measurement error and increase the value of credibility.

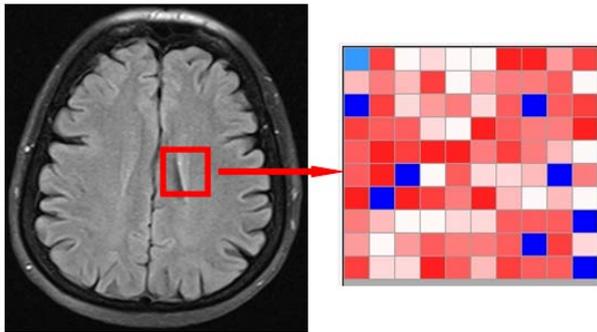


Figure 15. Brain

The user get the position of the cell in the grid (blue arrow in Figure 16), the value of the marker (yellow arrow in Figure 16), the inclusion of the interval (green arrow in Figure 16) and the value of the error (red arrow in Figure 16) by clicking at any cell. If the value of the marker is above the threshold (critical value), a exclamation sign Figure 16 symbolizing the area with an extremely increased value is visible.

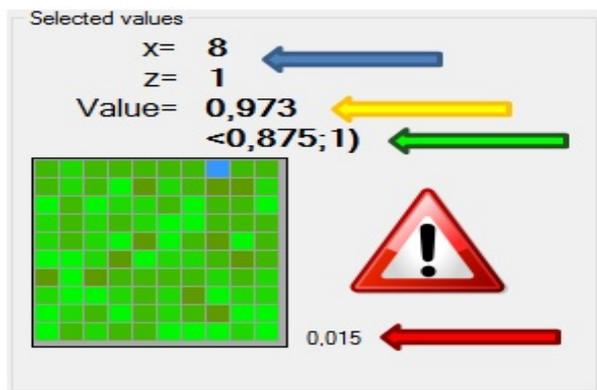


Figure 16. Marker values

15. 3D Model

Another type of presentation of the results of magnetic resonance imaging is 3D models that combine all 2D models. Each layer can be considered as a slice of the block. Individual slices are defined by the user in any way to display color anomalies. 3D model allows you to zoom and rotate the projection. This module uses the library "XNA Game Studio 4.0 Refresh," which has been developed and designed especially for gaming due to the speed and stability. The library can be integrated with any modern technology and offers very good quality of the figures, hardware acceleration.

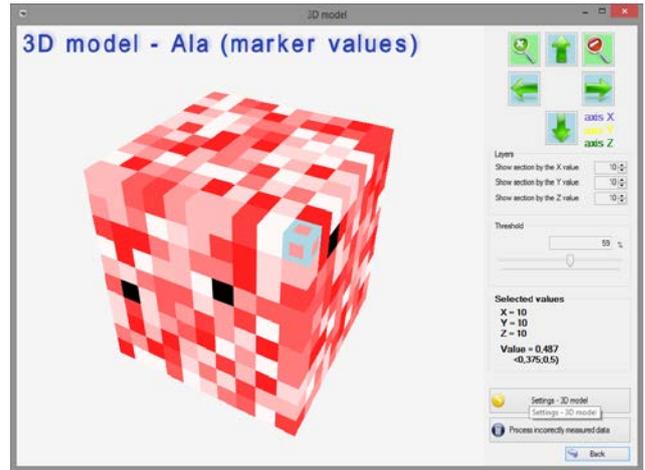


Figure 17. 3D model

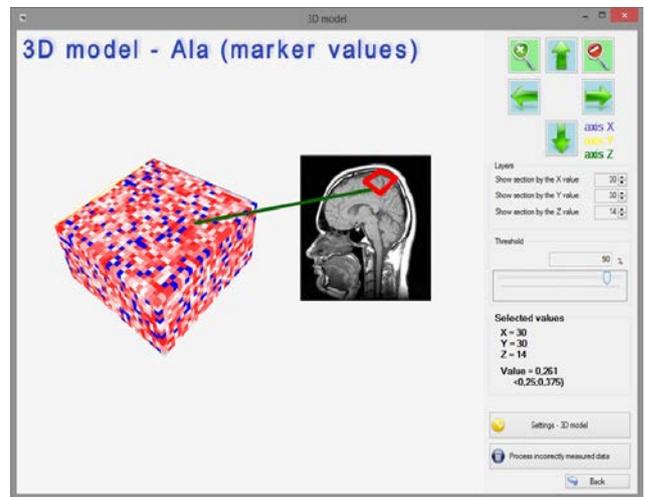


Figure 18. 3D model

3D model is based on textures.

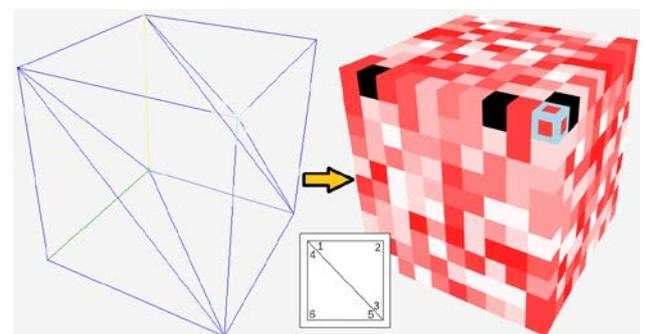


Figure 19. Textures

16. Comparison of Results

It is important to monitor the progress and effectiveness of the treatment during and also after the process of treatment of cancer. For this reason, the special module is created, that compares the results of the patient during the time intervals. Tolerance value (adjustable in the settings) expresses the maximum non-dangerous difference of the marker values of voxels in time. If the difference is greater than the tolerance, the user is notified.

The aim of this module as well as the entire application, is to simplify interpretation of the results, discover and locate anomalies, monitor the progress.

The following figure shows the current situation of the patient (right) and MRI scan made one year ago (left), where anomalies have not been detected. The exclamation sign reflects the increased value - exceeding the maximal accepted difference defined by tolerance values.

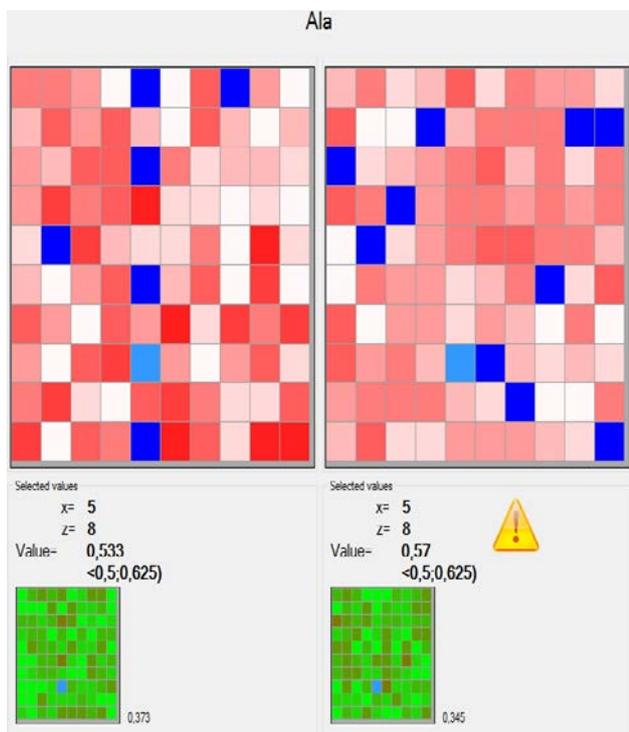


Figure 20. Comparison of results over time

17. Results

The result of the presentation is medically oriented applications aimed on displaying and processing the results of an MRI scan obtained by viewing the presence of certain specific markers in abnormal findings (especially tumors) inside the brain. Application has been developed on specific requirements of practice and is user (doctor) - oriented, allows to view and process the results of MRI based on the specific requirements and needs. The application offers a variety of views - 2D model, 3D models, results in the form of graphs and DataGrids.

It has been tested during the development based on results of volunteers in close collaboration with the University Hospital in Martin. Volunteers have been screened for in accordance with ethical and legal standards. CAT scans have been carried out under standard conditions MRI device Siemens Symphony 1.5 Tesla.



Figure 21. Siemens Symphony 1,5 Tesla

Based on the requirements, application offers the possibility to view the models on a computer with four monitors; data between windows are synchronized. Figure 22 shows the main window (top left) and the models. Figure 23 shows the 2D and 3D model and model to compare the results of the scan of the patient.

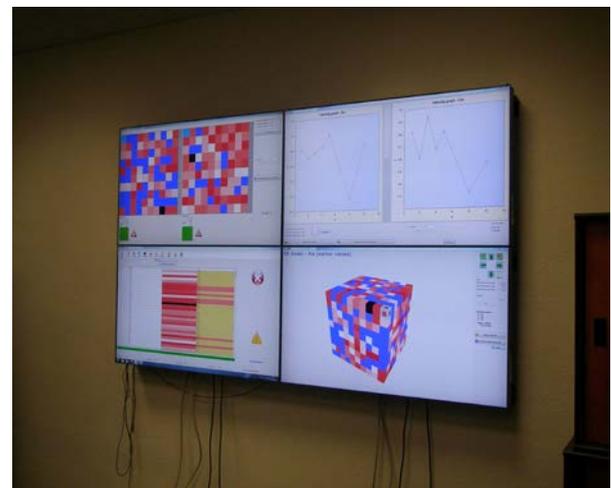


Figure 22. Application - 4 monitors computer

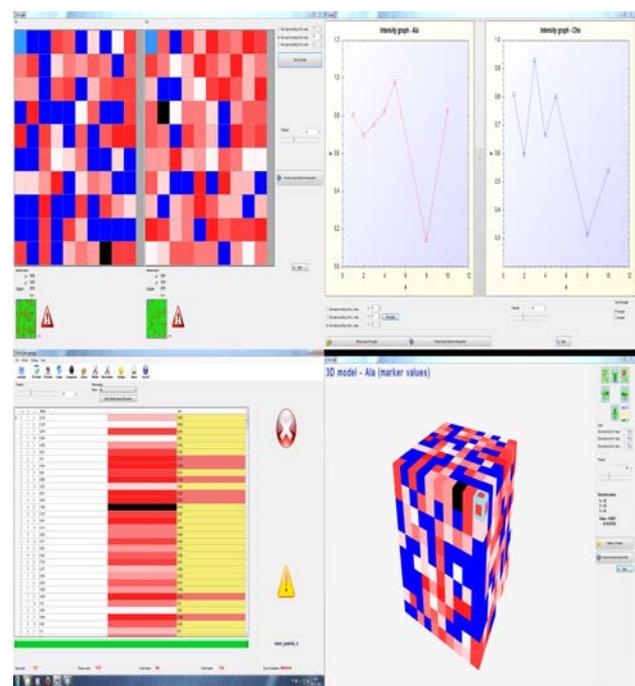


Figure 23. Application

18. Conclusion

Cancer is one of the most serious medical problems worldwide. Early diagnostics and adequate treatment is a key role for treatment of the patient.

Brain tumor detection project is one of the new parts of the Hospital information system project, created for the needs of the University Hospital in Martin, on the basis of long-term cooperation with the Faculty of Management Science and Informatics, University of Žilina.

The aim is to create a universal solution for processing the results of magnetic resonance imaging; to detect and locate brain tumors and provide results in the form of tables, graphs, 2D and 3D models based on user requirements. The aim of the application is to show the presence of markers - substances that are present in the tumor tissue. The application was designed to show the presence of both standard markers, but allows the user to enter additional markers based on the professional requirements (such as specific markers for predicting tumor type). It is also possible to save the results of magnetic resonance imaging and compare them in time.

The problem of the result processing magnetic resonance imaging is the measurement error in all investigated areas, some parts are measured with relatively high measurement error. Thus, we have created a module for processing the data in order to reduce measurement error and get the valid value of the referenced marker.

In a further development of the project, we will extend the database results and treatment methods to give the opportunity to compare and categorize different types of anomalies. Results of MRI is more convenient to store in temporal database, where only significantly changed values are stored.

The application has been developed in collaboration with the University Hospital in Martin, its use is not

limited to specific type of device, it can also be used in other hospitals. Application offers three languages – English, German and Slovak language allowing to use it abroad.

The solution is now tested at the Institute of Medical Biochemistry, Faculty of Medicine in Martin.

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