Quantitative assessment of the brain neural networks activation in dynamics

M Ya Marusina and A D Bukhalov
ITMO University, Kronverkskiy pr., 49 A, St. Petersburg, 197101, Russia
E-mail: marusina_m@mail.ru

Abstract. The quantitative estimation method of activation volumes of large-scale neural networks in a human brain in dynamics has been developed and tested. Processing of face recognition data in the human brain neural networks is carried out by the method of functional magnetic resonance imaging. The results of experiments showed that in the process of recognizing images of faces, the activation of the subjects’ brains differs in different phases of stimulation. The developed method allows one to obtain quantitative information on restructuring of large-scale neural networks of subjects. The results of the study can be used to create learning algorithms in computer vision systems.

1. Introduction
The term "Computer Vision" (CV) refers to the automatic capture and processing of images using computer tools, which allows user to interpret properly the real world.

In medical diagnostics, functional magnetic resonance imaging (fMRI), computer vision can be used for visualizing and extracting meaningful information, as well as making decisions based on the received information. Making decision is a complex dynamic process that includes various stages of processing information spaced apart in the brain regions and separated in time.

The fMRI method, which allows obtaining data on the activity of neurons by changing blood circulation in the brain, has a high spatial resolution, but a low temporal resolution. Therefore, there is the interest to track changes in brain activation in dynamics, in different phases of research (within minutes), when the operator performs the assigned task in different working conditions [1-9]. In the study [1], it was shown that individual maps of the activation of neural networks in the brain for different subjects significantly distinguish to each other in different periods of fMRI. This determines the relevance of developing reliable methods for quantitatively assessing the dynamics of information processing in neural networks when the operator performs the assigned task.

The purpose of the work is to create and test method for quantifying the volume of activation zones of large-scale neural networks of the human brain in dynamics. The results of the work can be used to create learning algorithms in computer vision systems, for example, in convolutional neural networks (CNN) and deep learning when performing tasks are in uncertain observation conditions [10-13].

2. Research methods
Images of the brain were obtained on a Siemens-Symphony magnetic resonance tomograph (1.5 T) with a gradient of 40 m T / m, using a transmitting and receiving radio frequency array coil. To obtain maps of activation of neural networks of the brain (36 slices) with a matrix of 64×64 pixels for 3 seconds, the technique of echo planar imaging (EPI) was used.
The fMRI method allows determining the activity of neurons in the brain by the changes in blood circulation. To visualize the response of the brain at the time of stimulation, the technique for measuring the level of hemoglobin oxygenation – BOLD (Blood Oxygenation Level Dependent) was used. Visualization of the most active areas of the brain at the time of stimulation is possible due to the difference in the magnetic properties of oxyhemoglobin and deoxyhemoglobin. The level of oxygen consumption by brain tissues, reflected in a change in the BOLD signal, can increase (activation) and decrease (deactivation).

To obtain reliable results on the number of activated voxels in the gray matter of the brain, standard post-processing data processing was used, such as elimination of artifacts, statistical processing with the construction of statistical maps, the combination of statistical maps with anatomical images, which allows localizing accurately the identification of the activation zone [14-22].

The results of psychophysics series of research were used, also certain and uncertain conditions of decision-making were simulated when the head rotations of the optoclone were recognized. The thresholds for recognizing the head rotation of the optoclone depended on the level of additive interference and the number of image pixels that changed during the study. In addition, fMRI scans of 11 persons were used, where people got 4 phases of stimulation, and duration of showing stimulation was 1000 ms, phases of stimulation lasted 30 seconds (10 scans for 3 seconds). As the result, averaged by all person’s statistical patterns of brain activation by the BOLD signal were obtained. The studies are presented in the Brodmann area 17 (BA17) of the visual cortex of the cerebral hemispheres.

3. Results

Image processing was used to find the maximum activation in the Brodmann zone 17 (BA17). The coordinates of any voxel in any Brodmann area are known. Using these coordinates, we can distinguish active voxels from one area from voxels from other areas. Whole number of voxels in Brodmann area 17 can be represented as 1. Then, by image analysis using brightness of any voxel, we can say about activity of it. Then, finding any voxels which activation is upper than some threshold level is in process. Therefore, to obtain percent of activation in Brodmann area 17 (BA17) we need to make a ratio by dividing the number of active voxels (upper than threshold) by the whole number of the voxels in the area. By this method, we can observe the percent of activation in any Brodmann area.

In the Figure 1 maximum activity of Brodmann area 17 (BA17) is pointed. The axial, coronary and sagittal brain projections are presented. Red zones represent more activity and blue zones low activity. The coordinates x, y, z stands for slices of the MRI images, where the point with coordinates x = 0, y = 0, z = 0 is the center of the brain.

![Figure 1](image-url)

**Figure 1.** Coordinates of the voxel with maximum activity in Brodmann area 17 (BA17), which are pointed on axial, coronary and sagittal projections of the subject’s brain.
Figure 2 shows the results of calculating the activation volumes of the Brodmann area BA17 at the selected activation threshold for various series of experiments. The calculations were carried out in the MATLAB environment. 28 series of experiments were carried out with showing various combinations of stimuli to 11 subjects. In different phases of stimulation, there was a change in the number of activated voxels on fMRI images that exceeded a statistically significant threshold. For example, in the first experiment the ratio equals to 0.4 that means that 40% of the BA17 was in active during the experiment. The threshold was chosen equal to 0.7, at which at least one active voxel exceeded this level in all series.

Figure 2. Ratio of active voxels of BA17 exceeding the statistically significant threshold to the entire volume of BA17 in 28 series.

4. Consideration
Time averaging of fMRI maps of brain activation does not allow us to demonstrate reliably the complexity of information processing in the subject's brain during stimulation. Probably, different large-scale neural networks of the brain are activated in different phases of stimulation. Consequently, the more data on the difference between neural networks from each other, for example, on the intensity of the BOLD signal or on the localization of active regions, the more differences there will be on statistical maps. Analysis of the brain activation maps of the subject for the entire fMRI period revealed the change in the number of activated voxels depending on the stimulation phases.

The presented method for quantitative assessment of the volumes of brain activation zones in dynamics makes it possible to analyze quickly and reliably a large amount of data obtained during
fMRI studies. The developed method allows comparing the results of studies carried out on different tomographic devices.

The developed method for quantitative assessment of the activity of biological neural networks in dynamics can be used in the development of computer vision systems for processing and visualization of significant information, as well as in the creation of learning algorithms in such systems.

5. Conclusions
The results of the experiments showed that in the process of recognizing images of faces, the activation of the subjects' brains differs in different phases of stimulation. Considering the dynamics of changes in the volumes of brain activation zones during fMRI allows obtaining information on the restructuring of large-scale neural networks in the brain of the subjects.

References
[1] Zhukova O V, Vasil’ev P P 2020 Reconstruction of a neural network and alteration of the operators’ strategies during the recognition of facial images. Journal of Optical Technology 87(10) 581-589
[2] Kalinkina M, Marusina M et al 2020 Opto-Electronics and Scanning System Calibration with Remote Sensing, Moscow Workshop on Electronic and Networking Technologies, MWENT 2020 - Proceedings, 9067358
[3] Flegontov A V and Marusina M J 2009 The Comparison Method of Physical Quantity Dimensionalities. Lecture Notes in Computer Science. 5743 LNCS 81-88
[4] Grigoryev K et al 2011 J. Phys.: Conf. Ser. 295 012168.
[5] Davydov R V et al 2019 J. Phys.: Conf. Ser. 1400 066037.
[6] Davydov R V et al 2019 J. Phys.: Conf. Ser. 1410 012067.
[7] Logunov S E et al 2019 J. Phys.: Conf. Ser. 1410 012113.
[8] Marusina M Ya, Kostenikov N A and Kaznacheeva A O 2010 Physical basis and equipment for positron emission tomography. National guidelines for radionuclide diagnostics (Tomsk: STT)
[9] Marusina M Y, Sizikov V S and Volgareva A P 2015 Noise suppression in the task of distinguishing the contours and segmentation of tomographic images. Journal of Optical Technology. 82(10) 673-677
[10] Liu F, Zhou Z, Jang H, Samsonov A, Zhao G and Kijowski R 2018 Deep convolutional neural network and 3D deformable approach for tissue segmentation in musculoskeletal magnetic resonance imaging. Magn Reson Med. 79 2379-91
[11] Ronneberger O, Fischer P and Brox T 2015 U-Net: Convolutional Networks for Biomedical Image Segmentation. Med Image Comput Comput Assist Interv. 9351 234-241
[12] Hou L, Samaras D, Kurc T M, Gao Y, Davis J E and Saltz J H 2016 Patch-Based Convolutional Neural Network for Whole Slide Tissue Image Classification. In: 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR). Silver Spring, United States, pp 2424-33
[13] Pezeshk A, Hamidian S, Petrick N and Sahiner B 2019 3D convolutional neural networks for automatic detection of pulmonary nodules in chest CT. IEEE J Biomed Health Inform. 23(5) 2080-90
[14] Dou Q, Chen H, Yu L, et al 2016 Automatic detection of cerebral microbleeds from MR images via 3D convolutional neural networks. IEEE Trans Med Imaging. 35(5) 1182-95
[15] Marusina M Y, Mochalina A P, Frolova E P, Satikov V I, Barchuk A A, Kuznetcov V I, Gaidukov V S and Tarakanov S A 2017 MRI Image Processing Based on Fractal Analysis. Asian Pacific Journal of Cancer Prevention. 18(1) 51-55
[16] Kiryakova T N, Marusina M Ya and Fedchenkov P V 2017 Automatic methods of contours and volumes determination of zones of interest in MRI images. REJR 7 (2) 117-127
[17] Marusina M Ya and Karaseva E A 2018 Automatic Segmentation of MRI Images in Dynamic Programming Mode. Asian Pacific journal of cancer prevention: APJCP 19(10) 2771-75
[18] Marusina M Ya and Karaseva E A 2018 Application of fractal analysis for estimation of structural changes of tissues on MRI images. *REJR 8*(3) 107-112

[19] Marusina M Y and Karaseva E A 2019 Automatic analysis of medical images based on fractal methods, *Proceedings of the 2019 IEEE International Conference “Quality Management, Transport and Information Security, Information Technologies” (IT & QM & IS), September, 23-27, 2019*, pp 349-352

[20] Marusina M Y and Karaseva E A 2019 Application of the box-counting method for the evaluation of medical images, *Proceedings of the 2019 IEEE International Conference “Quality Management, Transport and Information Security, Information Technologies” (IT & QM & IS), September, 23-27, 2019*, pp 353-355

[21] Shelepin K Yu, Trufanov G E, Fokin V A, Vasiliev P P and Sokolov A V 2018 Digital visualization of the activity of neural networks in the human brain before, during and after insight in image recognition, *Optical Journal* 85*(8)* 29–38

[22] Karaseva E A, Marusina M Ya and Andreev Yu S 2019 The Certificate on Official Registration of the Computer Program. Software package for automated fractal image analysis (FragLab). No 2019614337