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Research Paper

# Integrated MATLAB Toolbox for fMRI Visualization and Data Conversion

Hussain A. Jaber[1, 2, 3*], Hadeel K. Aljobouri[1, 3], Orhan M. Koçak[4], Oktay Algin[2, 5, 6], Ilyas Çankaya[3]

1. Department of Biomedical Engineering, College of Engineering, Al-Nahrain University, Baghdad, Iraq.
2. National MR Research Center (UMRAM), Bilkent University, Ankara, Turkey.
3. Department of Electrical and Electronics Engineering, Graduate School of Natural Sci., Ankara Yıldırım Beyazıt University, Ankara, Turkey.
4. Department of Psychiatry, Medical School, Psychiatry Clinic, Başkent University, Ankara, Turkey.
5. Interventional MR Clinical R&D Institute, Ankara University, Ankara, Turkey.
6. Department of Radiology, Faculty of Medicine, Ankara University, Ankara, Turkey.

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## ABSTRACT

**Introduction:** Working with functional magnetic resonance imaging (fMRI) often involves engaging with multiple file formats and complex viewers. In this study, we developed a novel platform as a visualization and conversion fMRI (VCfMRI) MATLAB toolbox for fMRI data.

**Methods:** The VCfMRI was developed to read and write 3D fMRI volumes in DICOM, NIfTI, ANALYZE, and MAT formats and convert between them, on a single user-friendly platform. It includes 62 functions across seven graphical user interface modules for conversion, batch read/write, and orthogonal viewing (sagittal, coronal, horizontal). This toolbox also supports overlaying statistical maps on anatomical images with adjustable thresholds. We built and tested VCfMRI using real datasets from a scanner (3T, Siemens Co.) at UMRAM, Bilkent University.

**Results:** VCfMRI successfully converted and visualized all supported formats in one environment, enabling synchronized 3D views and functional overlays with interactive threshold control, streamlining previously fragmented steps.

**Conclusion:** The VCfMRI toolbox provides a simple and efficient solution for fMRI data conversion and visualization. It simplifies the handling of fMRI datasets across different formats, which is especially beneficial for physicians, healthcare specialists, and researchers who face challenges in processing and visualizing multi-format neuroimaging data.

*** Corresponding Author:**
***Hussain A. Jaber, Assistant Professor.***
***Address:*** *Department of Biomedical Engineering, College of Engineering, Al-Nahrain University, Baghdad, Iraq.*
***Tel:*** *+90 (55) 45938218*
***E-mail:*** *hussainjaber2000@nahrainuniv.edu.iq*

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## Highlights

- A novel visualization and conversion fMRI (VCfMRI) toolbox is proposed.
- VCfMRI is enabled to read, write 3D volume data, and multi multi-conversion operations.
- Nearly 62 analysis functions and 7 graphical user interface tools for functional magnetic resonance imaging modalities are implemented.
- VCfMRI provides an easy way of handling this type of data.

## Plain Language Summary

Functional magnetic resonance imaging (fMRI) is a robust, noninvasive, and modern technique for imaging brain functions. The complexity of the raw fMRI data leads to significant challenges faced with multiple operations on these data, such as image conversion, reading and writing, extracting information, and so on. To overcome such difficulties and challenges, an indispensable initial stage in processing the fMRI dataset is to convert images from the complicated form (raw data) DICOM to the much simpler NIfTI (.nii or .nii.gz) or ANALYZE (.img/.hdr) format. In this work, a novel conversion and visualization fMRI (VCfMRI) toolbox is proposed. The VCfMRI tool is enabled to read, write 3D volume data (.dicm, .nii, .img, hdr, and .mat format), as well as perform multi-conversion operations between them, are performed in the same package. This toolbox is designed and implemented under the MATLAB platform and 64-bit Windows environment for visualizing fMRI time series data. In the current work, real fMRI data are used and classified into three groups, which are named the night group, the healthy control group, and the full day group. The data acquired by a magnetic resonance imaging scanner type Siemens/3T in the National Magnetic Resonance Research Center (UMRAM) in Turkey, Ankara. About 62 analysis functions have been implemented and incorporated in analysis, about 7 graphical user interface tools for multiple conversions of fMRI modalities, reading/writing and viewing in all fMRI data formats, visualizing 3D (sagittal, coronal, and horizontal slices) statistical and non-statistical neuroimaging, thresholding, and overlaying. This work enables the user to visualize and deal with fMRI data efficiently, especially for physicians, healthcare specialists, and researchers who face challenges in handling this type of data.

## 1. Introduction

Medical imaging is well-known in the clinical and other research areas, with several equipment constructors providing a varied range of modalities. Many of the general tools used for technical image processing, analysis, and visualization involve images to be stored in the NIfTI and ANALYZE file formats, while scanners accustomed to obtaining these images usually export data in the DICOM format. These two formats are appropriate for their specific function; DICOM is comprehensive and effusive, whereas NIfTI is smooth and straightforward to support. Thus, a mutual first step in every neuroimaging analysis is to convert the images from DICOM to NIfTI format (Li et al., 2016; Mildenberger et al., 2002; Ashby, 2014; Larobina & Murino, 2014). This paper aims to develop a novel platform as a visualization and conversion functional magnetic resonance imaging (VCfMRI) MATLAB toolbox for fMRI data to address various issues faced while visualizing and converting multi-modal neuroimaging data, especially the complexity problem. The grouping of analyses from many imaging modalities is a significant and developing trend in neuroimaging (McDonald, 2008; Stufflebeam & Rosen, 2007). Researchers are aware of the limitations of different imaging techniques and their related analysis approaches (Orden, 2006). Multi-modal methods are used to achieve differences in results acquired from different methods (Liu et al., 2006) and organize for joining evidence about researchers' hypotheses.

Several neuroimaging analysis packages are presented to researchers, assisting analysis of data from a complex and varied range of data acquisition systems. The Neuroimaging Informatics Tools and Resources Clearinghouse (NIF-TI, 2019) introduced numerous tools. Commercial analysis software packages comprise ANALYZE (AnalyzeDirect, 2019) and BrainVoyager (BrainVoyager, 2012). There are several open-source analysis toolboxes widely used for MATLAB, which are exemplified by statistical parametric mapping (FIL Methods Group, 2019), Fieldtrip (Oostenveld et al., 2011), EEGLAB (Delorme & Makeig, 2004), mrVista (Teo et al., 1997), and NUTMEG (NUTMEG, 2019). Stand-alone, cross-platform analysis packages comprise FSL and Free Surfer (FreeSurfer, 2019; FSL–FslWiki, 2019). In addition to analysis packages, several stand-alone visualization packages have been developed, some of them complement particular analysis packages (e.g. FSL's FSLView (FslView, 2019) and others individually of analysis packages, MRICron (MRIcron Index, 2019) and 3D Slicer (3D Slicer, 2019). Both analysis and stand-alone visualization packages are often modified results advanced by to meet a site's particular requirements.

The problem of choosing the method to overcome these difficulties and challenges is still open. An indispensable initial stage in processing the fMRI dataset is to convert images from the complicated form (raw data) DICOM to the considerably simpler NIfTI (.nii or .nii.gz) or ANALYZE (.img/.hdr) format. Accordingly, in this study, a new conversion and VCfMRI toolbox is proposed and implemented. The paper is organized as follows: 1) The fMRI data format conversion has been described in the second section; 2) The details of the software framework design and results have been presented in the third section; and 3) Discussions and conclusions are presented in section 4.

## Functional magnetic resonance imaging data formats conversion and reading

Image file formats arrange for an identical system to collect the information of an image in a computer file. A medical image is typically represented as either an image plane or a volume. The image plane is made of one or more images on behalf of the analysis of an anatomical volume. The volume is made of a series of images on behalf of thin slices. The file format refers to in what way the image data is structured inside the image file and in what way the pixel data should be construed by software for accurate loading and visualization.

fMRI image file formats can be divided into two categories, as shown in Figure 1. The first one is the format planned to systematize the images created by diagnostic modalities, e.g. DICOM (Bidgood et al., 1997). The second one is the formats trained with the intention to enable and support post-processing analysis, e.g. Analyze (Robb et al., 1989; Whitcher et al., 2011; Eloyan et al., 2014), Nifti (Neuroimaging Informatics Technology Initiative, 2019; Filippi, 2009).

Medical image files are stored in one of the following two arrangements. One where a single file holds together the metadata and image data, using the metadata stored at the beginning of the file. This paradigm is used by DICOM and Nifti file formats, even if it is acceptable by other formats. The second arrangement stores the metadata in one file while the image data is stored in a second file. The Analyze file format conforms to the two-file paradigm (.hdr and .img). In this part, characterize some of the most popular formats: Analyze, Nifti, and DICOM. The features of the term file formats are summarized in Table 1.

General-purpose programming languages like MATLAB do not support any of these formats. Therefore, a researcher who writes their MATLAB code for any data analysis step has to convert from one of these standard formats to a format that is MATLAB compatible. Popular software packages, such as SPM (FIL Methods Group, 2019; Ashburner, 2012) and FSL (Jenkinson et al., 2012), provide such code. The data that comes off the scanner with most MR systems is in DICOM format. Therefore, the first step in the data analysis process is to convert the data from DICOM to some other format (Grahamet al., 2005; Behroozi & Daliri, 2011; Behroozi, 2013). Fortunately, there are various software options for performing this task. Throughout this conversion process, it is possible that some supporting information would be lost. For example, the Analyze format tends

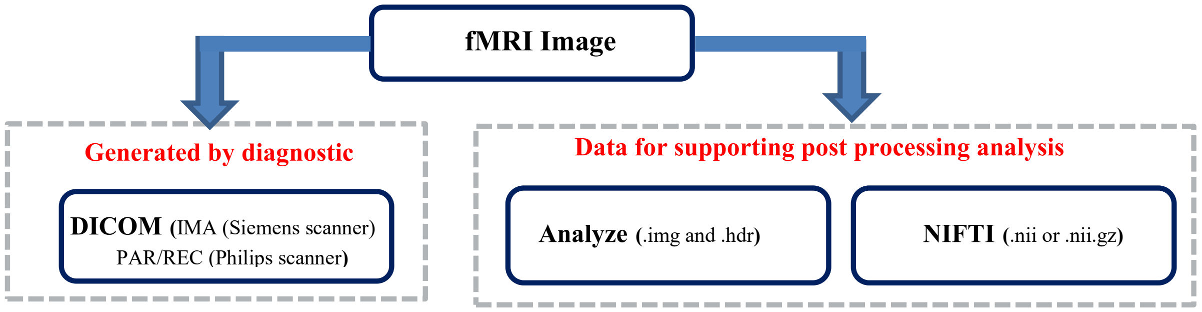


**Figure 1.** Functional magnetic resonance imaging data categories

fMRI: Functional magnetic resonance imaging.

**Table 1.** Characteristics of fMRI data formats

| Format Name | Data Types | Origin | Header | File Extension | Save Data | Handling |
|---|---|---|---|---|---|---|
| DICOM | Both signed and unsigned integers are (8, 16, and 32-bit, float not supported). | American College of Radiology (ACR)/ National Electrical Manufacturers Association (NEMA) | A binary format, Variable-length | IMA (Siemens scanner) PAR/REC (Philips scanner) | Raw image data in DICOM is saved as 2D image slices. | Handling several hundred of DICOM files. |
| Analyze | Signed integer (16 and 32-bit); unsigned integer (8 bit); complex (64-bit); float (32-, 64-bit) | Analyze software, Mayo Clinic | A binary format, Fixed-length: about 348 bytes | Two extensions (.hdr and .img) | Image data in Analyze is saved as a 3D image. | Handling two images of files. |
| NIfTI | Both signed and unsigned integer (8 to 64 bit); complex (64 to 256 bit), float (32 to 128 bit) | NIH Neuroimaging Informatics Tools Initiative | A binary format, Fixed-length: About 352 bytes | .nii or .nii.gz | Raw image data in NIfTI is saved as a 3D image (when it is used in SPM but 4D image if it is used in FSL). | Handling a single NIFTI file. |

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to have smaller headers than those of DICOM or NIfTI. Accordingly, when converting from either DICOM or NIfTI to Analyze, it is possible that some of the header information would be lost. However, more importantly, all of the intensity values collected from the scanner will be retained.

The initial stage for converting DICOM to NIFTI format is to classify DICOM files into different series. The DICOM concatenation involves a pack of DICOM images that were created altogether with the same magnetic resonance imaging (MRI) machine in the same process. There are two ways to classify DICOM to specific series; first, it is the most authoritative way of sorting series by DICOM objects like UID. The second way had been done by gathering objects "Patient Name," "Series Number," and "Study ID." Within every set of the series, if possible, it requires classifying images into different volumes. The instance number usually determines this. For certain kinds of files, one or more of the following DICOM objects are necessary for a reliable sorting of images in a series as echo number, acquisition number, image type, and image position patient. After that, the images in a series can be accumulated in an image containing up to seven dimensions.

For projection voxel indices into position in a coordinate system, the transformation matrix is utilized; the DICOM Patient Coordinate System is shown in Figure 2.

Typically need the following DICOM objects are needed to structure the transformation matrix. The first DICOM object is image orientation patient, which comprises two triplets ($r_x$ $r_y$ $r_z$ $c_x$ $c_y$ $c_z$) and the main function is to encode the cosine orientation of the column and row of the image slice. The second DICOM object is the image position patient of the first slice in a given volume ($x_1$, $y_1$, and $z_1$) is the coordinate of the x, y, and z in the voxel of the top-left corner of the first slice. Through the two above parameters, it is easy to determine the position of certain slices in the patient coordinate system. To locate the position of the volume, the image position patient parameter of the other slice is usually required. The size of a voxel is stored in the pixel spacing of the DICOM object inside the slice plane ($v_r$, $v_c$).The Equation 1 is used to construct the transformation matrix of DICOM coordinates, and n refers to the sum of the slices in the volume.

$$1.\ R_{DICOM} = \begin{bmatrix} r_x v_r & c_x v_c & \frac{(x_n - x_1)}{(n-1)} & x_1 \\ r_y v_r & c_y v_c & \frac{(y_n - y_1)}{(n-1)} & y_1 \\ r_z v_r & c_z v_c & \frac{(z_n - z_1)}{(n-1)} & z_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The Equation 2 is used to construct the transformation matrix of NIfTI coordinates. Firstly, the positive sign of the first two rows in equation 1 ($R_{DICOM}$) is changed to a negative sign to reflect the dissimilarity in the NIfTI coordinate system. The NIFTI system uses used RAS coordinate, which is a positive coordinate and refers to right, anterior, and superior. The is based on the NIfTI header, where the first three rows refer to rows of the affine transform, which are three items in the header of the NIFTI file. The third column is similar to and which comprises the slice thickness info. The thickness of the slice is usually determined by the DICOM object spacing.

$$2.\ R_{NIFTI} = \begin{bmatrix} -r_x v_r & -c_x v_c & -\frac{(x_n - x_1)}{(n-1)} & -x_1 \\ -r_y v_r & -c_y v_c & -\frac{(y_n - y_1)}{(n-1)} & -y_1 \\ r_z v_r & c_z v_c & \frac{(z_n - z_1)}{(n-1)} & z_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

There are many software packages listed in Table 2 that support multiple fMRI data formats, whether open source or commercial versions in the neuroscience area or fMRI area for visualization or conversion of data, but not all of them do not have all possibilities of the conversion of fMRI data format or all displaying modalities. However, the main contribution of the current work multiple conversion processes for all fMRI data formats are proposed and tested successfully in our lab.

In the current work, real fMRI data are used and classified into three groups, which are named the night group, the healthy control group, and the full day group. The night group consists of ten subjects, the healthy control group consists of ten subjects, while the all-day group consists of 11 subjects. The experiment stimuli were chewing and biting, all data were acquired by an MRI scanner type Siemens/3T in the National Magnetic Resonance Research Center (UMRAM)-Bilkent University.

There are 12 conversion processes of fMRI data format performed in the current work (Table 3). This software package contains all conversion processes, so that it will be the first in the literature. Another vital purpose of the VCfMRI tool is to visualize all modalities of fMRI data format in one package.

## Software framework design and results

The conversion and VCfMRI tools consist of three main parts: First, conversion modalities; second, loading, reading, writing, and visualization all fMRI data formats, third miscellaneous functions. The startup window of VCfMRI tools consists of multiple push buttons is shown in Figure 3.

At the start of the application, the first step provides the multiple conversion operations of all fMRI data formats (.dcm, .nii, .img, hdr, and .mat format). This step is performed through nine buttons to perform 12 matematical conversion processes that reflect all conversion possibilities between them (Figure 4).

When the user clicks the button “DICOM_IMG_NIFTI to .mat Conversion,” the .mat conversion image conversion window in Figure 5 appears. From the pop-up menu, the user can select one of the three types of fMRI data (.dcm, .nii, and .img/hdr). After appropriate selec-

**Table 2.** Programs that support multi-functional magnetic resonance imaging data formats

| Software Program | Format |
|---|---|
| SPM | Analyze (.img/.hdr), NIFTI(.nii) |
| FSL | NIFTI (.nii or nii.gz) |
| MRICRO | Analyze (.img/.hdr) |
| MRICRON | NIFTI (.nii or nii.gz) |
| ANALYZE | Analyze (.img/.hdr) |
| Mri3dx | Analyze (.img/.hdr) |
| NIFTI | NIFTI (.nii) |
| Slice Overlay | Analyze (.img/.hdr) |
| FreeSurfer | NIFTI (.nii) |
| AFNI | Analyze (.img/.hdr), NIFTI(.nii) |
| oro.nifti | NIFTI (.nii) |
| arf3DS4 | NIFTI (.nii) |

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**Table 3.** List of 12 conversion processes of functional magnetic resonance imaging data formats

| Conversion Process Name | Input Data | Output Data |
|---|---|---|
| DICOM to .MAT | DICOM | .MAT |
| NIFTI to .MAT | NIFTI | .MAT |
| Analyze (.img/.hdr) to .MAT | Analyze (.img/.hdr) | .MAT |
| DICOM to NIFTI | DICOM | NIFTI |
| DICOM to ANALYZE | DICOM | ANALYZE |
| .MAT to NIFTI | .MAT | NIFTI |
| Analyze (.img/.hdr) to NIFTI | Analyze (.img/.hdr) | NIFTI (.nii) |
| NIFTI to 2 D DATA | NIFTI | 2 D DATA |
| Analyze (.img/.hdr) to 2 D DATA | Analyze (.img/.hdr) | 2 D DATA |
| NIFTI to Analyze (.img/.hdr) | NIFTI (.nii) | Analyze (.img/.hdr), |
| 3D to 4D | 3D with multiple volumes (multiple files) | 4D with all volumes in one file |
| 4D to 3D | 4D with all volumes in one file | 3D with multi-volumes (multiple files) |

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tions, the dataset is loaded, and the header of this file is read and converted to the .mat format.

By clicking on the "DICOM to _NIFTI Conversion" button, the DICOM selection window appears. In the developed tool, a convenient feature for selecting only DICOM files exists. After the file selection process, the dataset is read and converted to .nii file format.

When the user clicks the "DICOM to img/hdr Conversion" button, the DICOM selection window appears. The user can select the desired DICOM files, and the selected files are loaded. Subsequently, the dataset is read and converted to the img/hdr file format.

By clicking on the ".mat to NIFTI Data Conversion" button, the .mat selection window appears. In the developed tool, a very convenient feature for selecting only

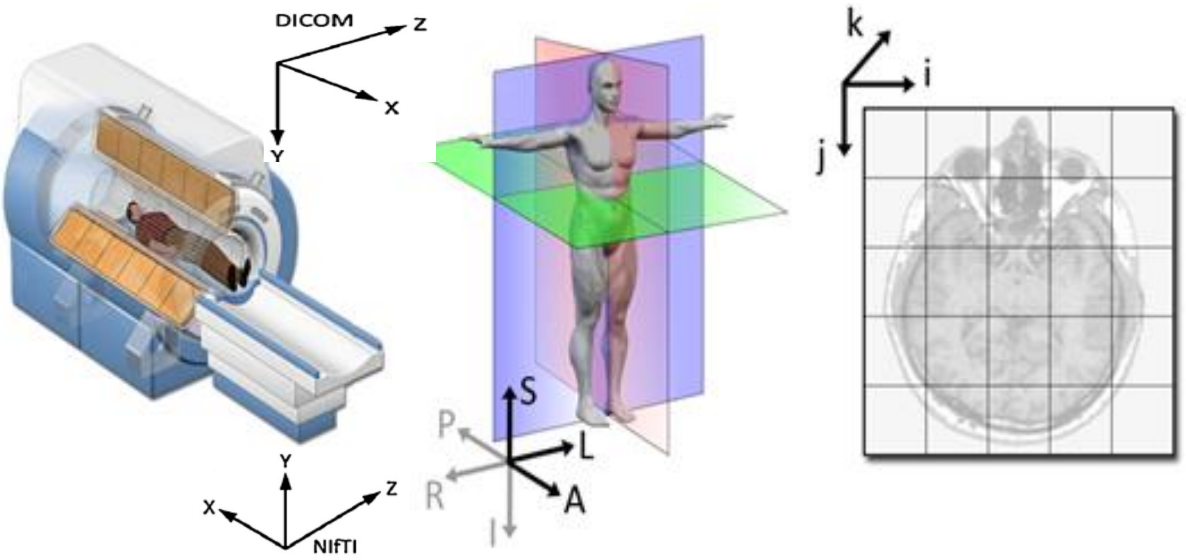


**Figure 2.** DICOM and NIFTI patient coordinate system

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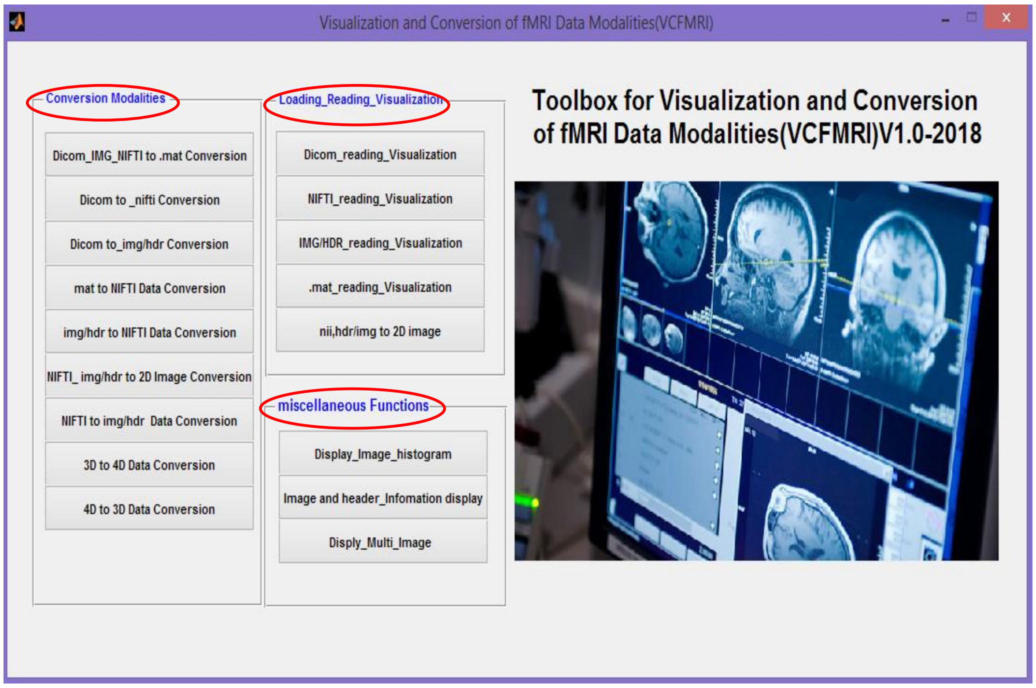


**Figure 3.** Startup window of visualization fMRI tools

.mat files exists, as shown in Figure 6. After the file selection process, the dataset is read and converted to a .nii file format.

Also, clicking on the "img/hdr to NIFTI Data Conversion" and "NIFTI to img/hdr Data Conversion" buttons is achieved in the same way as the previous button. The presented tool gives a very convenient feature for selecting only .img/hdr files and .nii, respectively. After the file selection process, the dataset is read and converted to a .nii file format and separate header and image data files (.img/hdr), respectively.

Clicking on the "NIFTI_ img/hdr to 2D Image Conversion" button enables users to convert fMRI data formats (NIFTI and Analyze) to a 2D Image format. This conversion is different from the above conversion pro-

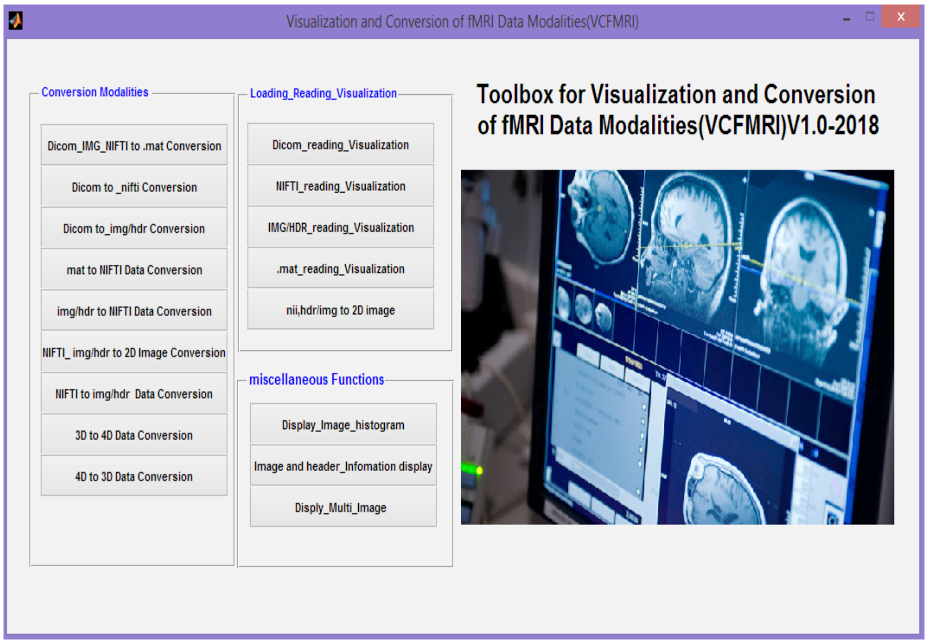


**Figure 4.** Conversion modalities section

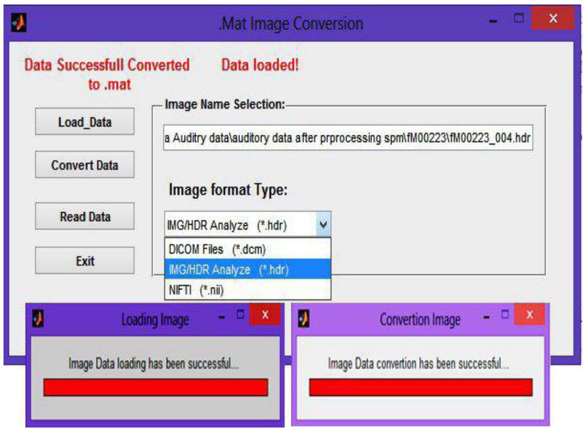


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**Figure 5.** DICOM_IMG_NIFTI to .mat conversion

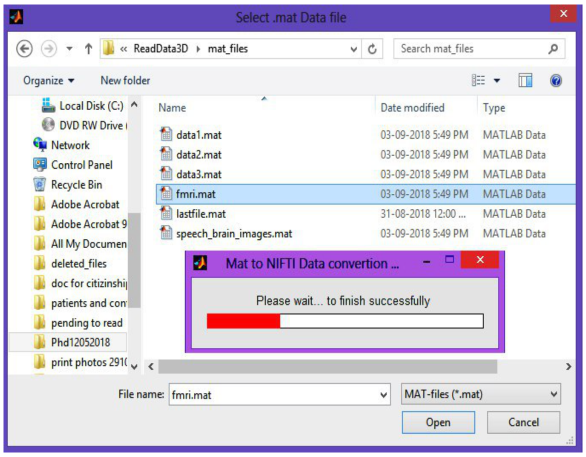


**Figure 6.** Selection .mat data window

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cesses because the output results appear as a 2-dimensional data file.

When the user clicks this button, the "Creating 2D fMRI data" graphical user interface (GUI) window appears (Figure 7). The desired "Create img to 2D Image" or "Create nii to 2D Image" button can be selected by the user, and the selected dataset is loaded and read (.img/hdr or .nii). A new 2D matrix data image is created, and the output result is displayed as a 2D fMRI image (Figure 7) by clicking the "View fMRI Data" button.

A "3D to 4D Data Conversion" button enables the user to convert fMRI data format nii with all volumes to the nii.gz. This means all fMRI data files (multi-volume files) can be converted to a compressed file (one file). When the user clicks on this button, a 3D to 4D conversion window appears. The desired 3D files can be selected by the user, and the selected 159 files (volumes) in our case are loaded and saved as a one output .nii.gz file.

Finally, and inverse to the last button, a "4D to 3D Data Conversion" button enables the user to convert fMRI data format .nii.gz (compressed one file) to .nii with multi-volume files. When the user clicks on this button, a 4D to 3D conversion window appears. The desired 4D file can be selected by the user, and the selected .nii.gz file is loaded and saved as the 159 output .nii files in our case.

The second part of the designed tool is the "Loading_ Reading_ Visualization" module, which consists of multiple visualization operations of all fMRI data formats (.dcm, .nii, .img, hdr, and .mat). This part is controlled with five buttons to perform five visualization processes that reflect all visualization possibilities for all fMRI data (Figure 8). In the developed tool, a beneficial feature for helping the users also exists. The user can read header data and write all types of fMRI data formats in a simple GUI design.

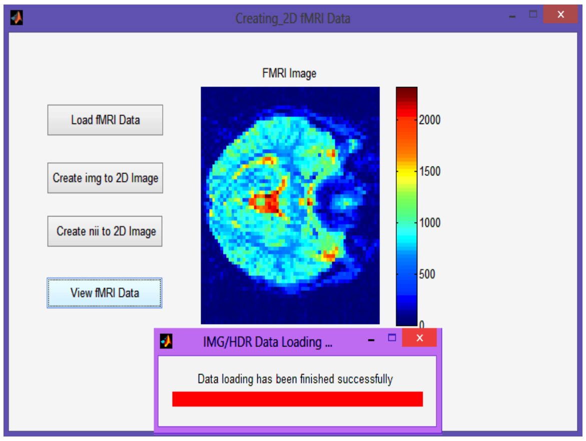


**Figure 7.** Creating 2D fMRI data

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**Figure 8.** Loading_reading_visualization part

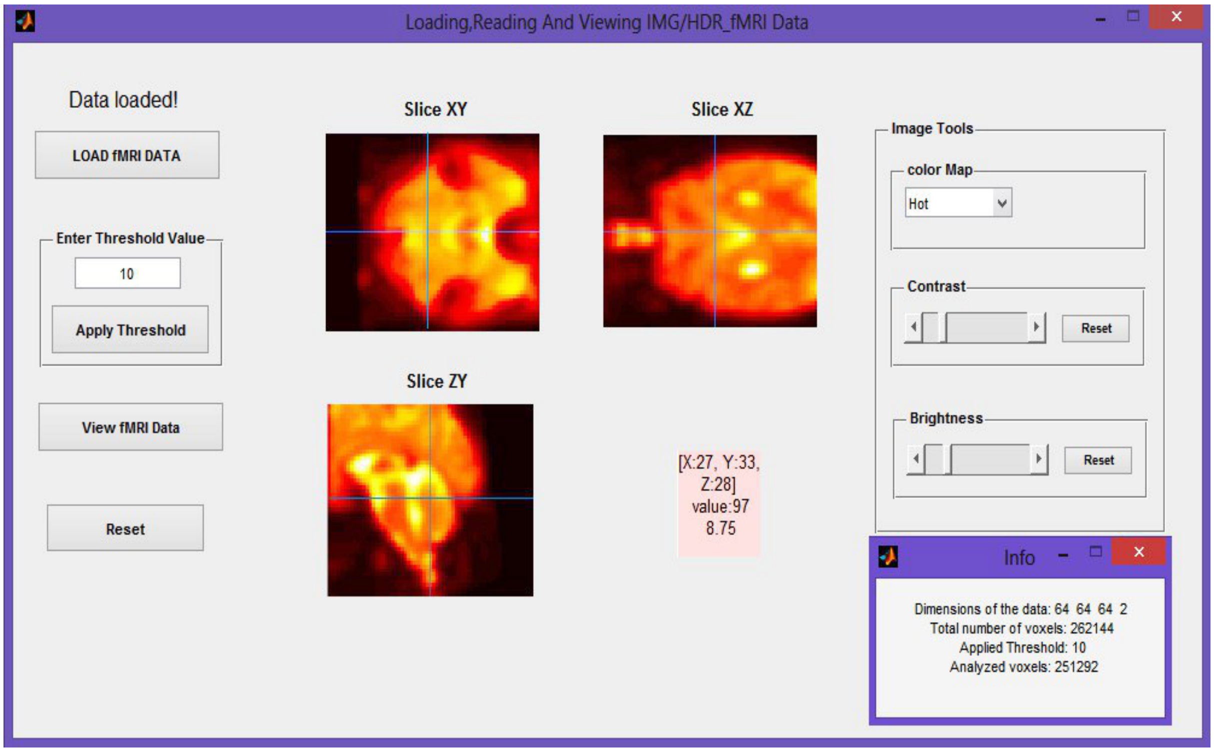


**Figure 9.** DICOM_reading_visualization

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When the user clicks the "DICOM_ reading_ Visualization" button, the "Loading, Reading and Viewing DICOM Data" GUI window appears (Figure 9). In the designed GUI window, many features of DICOM fMRI data processing exist. The desired DICOM folder (at the left of Figure 9) can be selected by the user, and the program makes analyses for calculating the number of images. When the analyses are finished, the selected data are saved automatically in the working directory. For the desired number of images, DICOM series images are

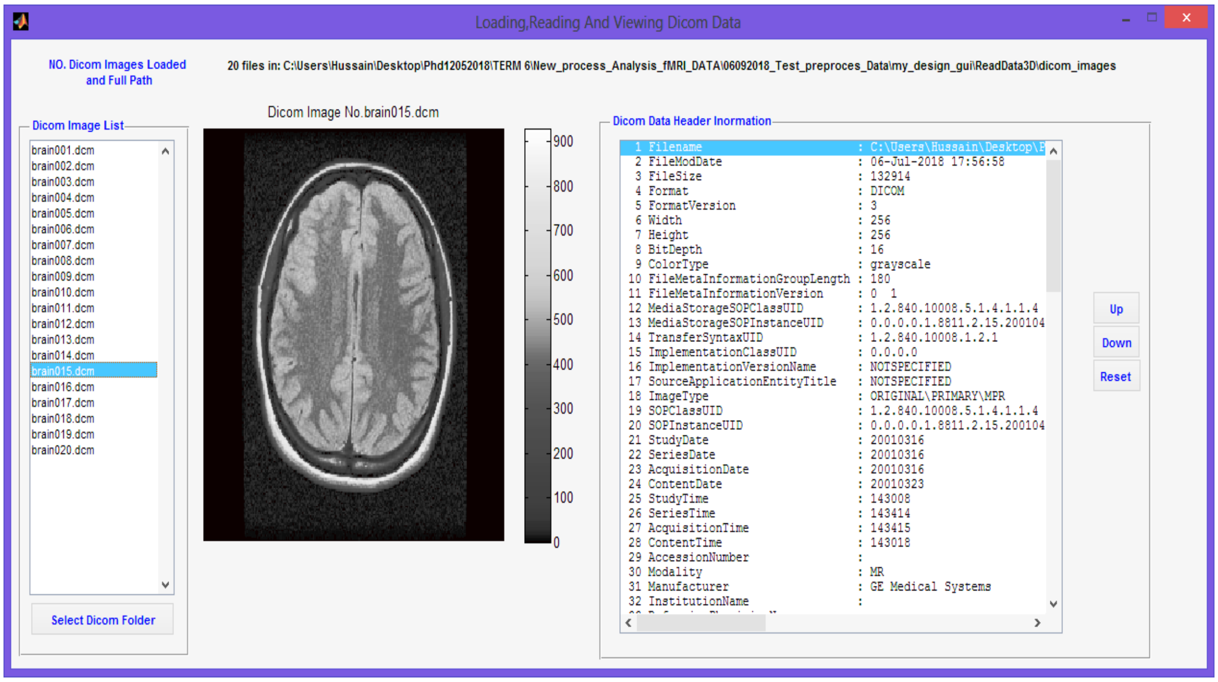


**Figure 10.** NIFTI_reading _visualization

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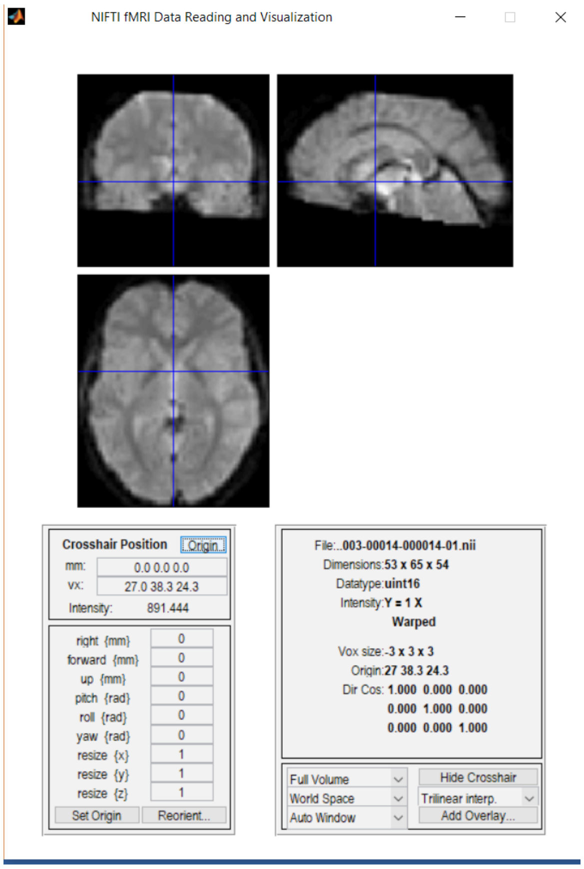


**Figure 11.** IMG/HDR_reading_visualization

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easily displayed and read the header (at the right of Figure 9), which includes all information about this image. In the presented GUI, a very convenient feature to deal with the large volume of the DICOM header work out. Also, some get-up-and-go buttons can be selected by the user to navigate between rows of the header or use the scroll bar of the list box of header information.

When the user clicks the "NIFTI_ reading_ Visualization" button, the NIFTI fMRI window appears (Figure 10). For the desired .nii file, the NIFTI image is readily displayed, and the header.

When the user clicks the "IMG/HDR_ reading_ Visualization" button, a new GUI window appears (Figure 11). In the designed GUI window, many features of

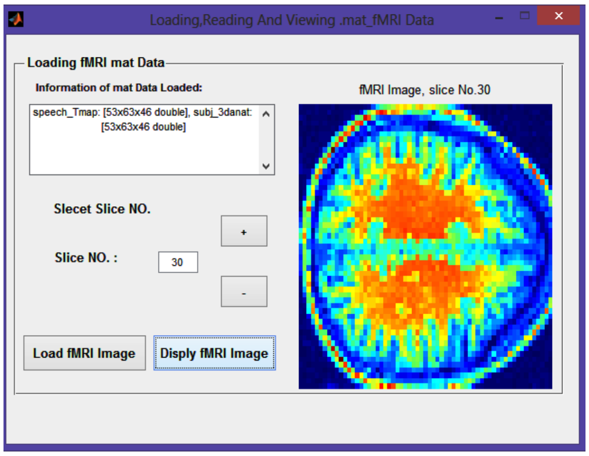


**Figure 12.** .mat_reading_visualization

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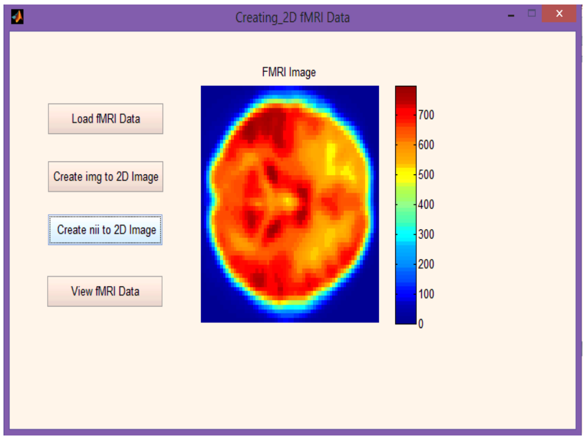


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**Figure 13.** nii, hdr/img to 2D image visualization

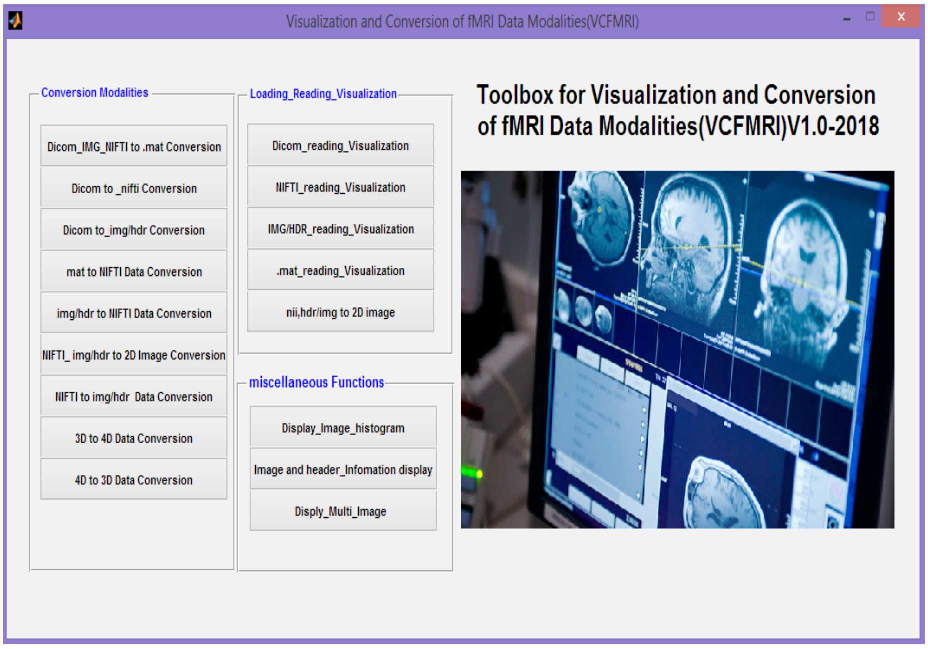


**Figure 14.** Miscellaneous functions part

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IMG/HDR fMRI data processing exist. The "Load fMRI Data" button at the left of Figure 11 enables the user to select a pair of fMRI files (.img and .hdr). After appropriate selection, the program makes analyses for calculating the number of voxels, the applied threshold, and the dimension of the data. In the presented GUI, a very convenient feature to display the IMG/HDR fMRI Data in 3-dimensional (sagittal, coronal, and horizontal slices) exists. An additional important feature of this GUI tool (at the right of Figure 11) is that it presents the user with an easy way to deal with contrast, brightness, and color map properties (the 8-color map is used).

When the user clicks the ".mat_ reading_Visualization" button, a new GUI window appears (Figure 12). In the designed GUI window, many features of .mat fMRI data processing exist. The "Load fMRI Image" button at the left of Figure 12 enables the user to load .mat data. Normally, both functional and structural fMRI datasets are stored in the same .mat file. After appropriate file selection, the program makes analyses for calculating

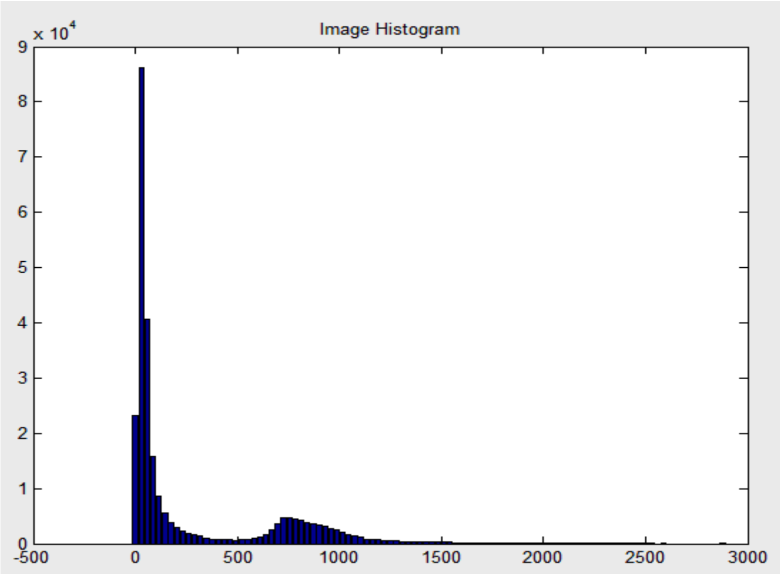


**Figure 15.** Display_image_histogram

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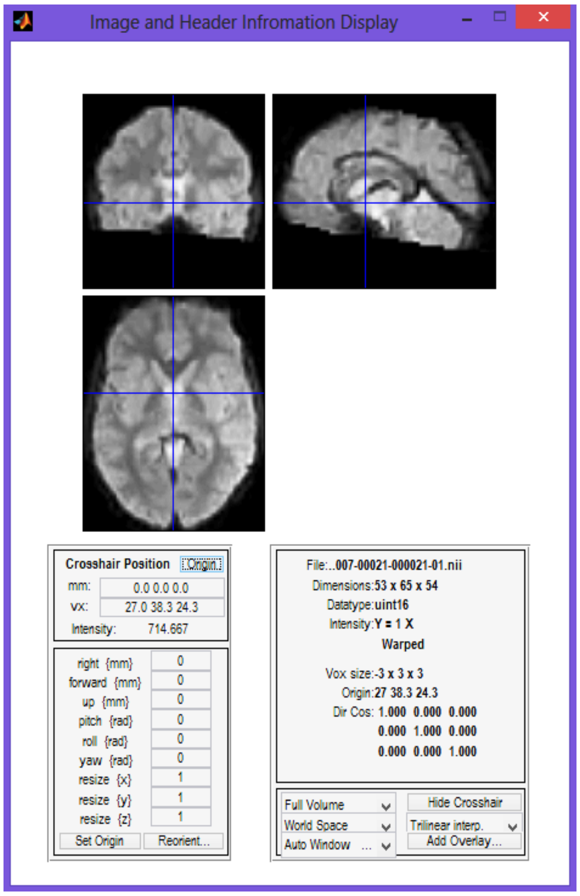


**Figure 16.** Image and header_ information viewer

the dimension of the functional and structural dataset. In the presented GUI, a very convenient feature to display the .mat fMRI Data in a slice-by-slice way is out. An additional important feature of this GUI tool is that it provides the user an easy way to display the desired fMRI data slice by slice (at the right of Figure 12), and navigate between them through control buttons (+ and -).

When the user clicks the “nii, hdr/img to 2D image” button, a new GUI window appears (Figure 13). In the designed GUI window, the “Load fMRI Data” button on the left of Figure 13 enables the user to load .img/hdr or .nii files. After appropriate selection, the user can select either the “Create img to 2D Image” or “Create nii to 2D Image” button to create a new 2D matrix data image. The created 2D image can be displayed by clicking the “View fMRI Data” button.

The third part of the tool is the “Miscellaneous Functions” part, which includes displaying the image histogram, display the image and header information, and display more than one image in the same figure (Figure 14).

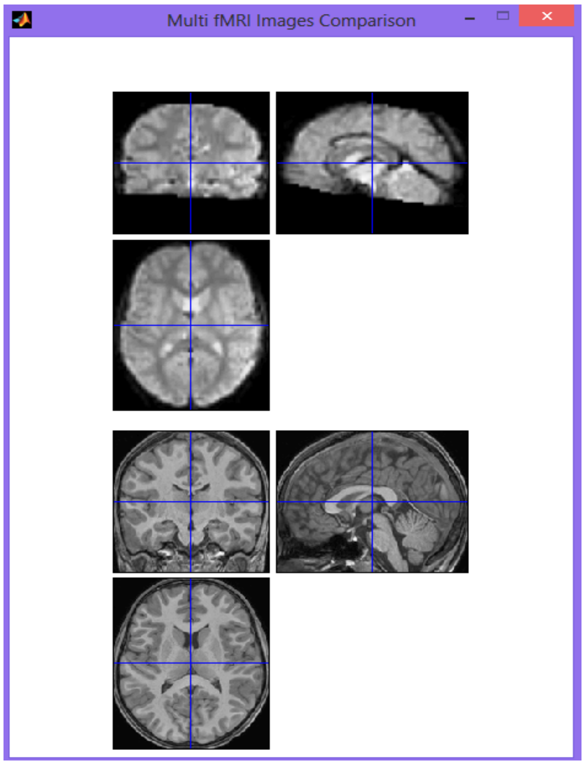


**Figure 17.** Display_ multi_ image comparison

When the user clicks the “Display_ Image_ histogram” button, image histogram function introduces. As seen in Figure 15, the user can display the histogram of any fMRI image format.

When the user clicks the “Image and Header_ Information Display” button, the “Image and Header Information” window appears. As seen in Figure 16, the user can read any format of fMRI image with its important header information; such as file name, dimension, data type as well as the crosshair position of the image and other functions.

When the user clicks the “Disply_ Multi_ Image” button, the “Multi fMRI Image” window appears. As shown in Figure 17, the user can display more than one fMRI images in the same graph. Also, the user can compare between two images, such as functional and structural fMRI images or display multi-contrast images to see a different contrasting area of multi-contrast images.

## Discussion

The proposed VCfMRI toolbox package is designed and developed to address many of the problems when visualizing multi-format fMRI data. This toolbox is implemented under the MATLAB platform and a 64-bit

Windows environment for visualizing fMRI time series data. The integration of multi-conversion processes of multi-format fMRI data is an essential and first step for preparing fMRI data for post-processing analysis, namely statistical analysis.

DICOM is an inconvenient format for fMRI data analysis. One problem is that a single fMRI session typically generates several thousand DICOM files. Furthermore, each of these files includes its header, even though all of these separate headers are mostly identical. Thus, a single fMRI session creates an enormous number of large DICOM files that contain much redundant information. All of these files make data analysis difficult, so the raw DICOM files are often converted to any other more convenient format (like NIFTI and ANALYZE format) before data analysis begins.

The proposed VCfMRI package is an authoritative and straightforward tool to address numerous issues related to multi-format fMRI data, especially visualizing and converting between all of these types of data. Therefore, the package provides the following main features:

1. Conversion tools of fMRI modalities;

2. Converts fMRI raw data to a more friendly and straightforward format, such as Analyze, NIFTI, and .mat format;

3. VCfMRI package can view diverse fMRI image formats, such as Analyze, NIFTI, .mat, and 4D

4. Create 2D fMRI data;

5. Export images to MATLAB format;

6. Reading/writing and viewing of all fMRI data formats;

7. Visualizing 3-dimensional (sagittal, coronal and horizontal slices);

8. Reference and based tools, especially for physicians, healthcare specialists, and researchers who face challenges in handling this type of data;

9. User-friendly for comprehensive neuroscience tools because it contains all fMRI data formats (DICOM, ANALYZE, NIFTI, and MAT) conversion modalities.

## Conclusion

In conclusion, the unique features of the VCfMRI toolbox lie in its specific design for the direct handling of fMRI data conversion processes. Based on our experience and review of many works of studies on the fMRI data conversion, this work will be the first in the literature because there are no software packages that contain all conversion processes like our toolbox. In the VCfMRI package, 12 conversion processes of fMRI data format are performed, as well as the ability to visualize all modalities of fMRI data format in one package.

The current proposed work is comprehensive, very necessary, and has vital significance, especially for physicians in the neuroscience area, healthcare specialists, engineers, and researchers who face challenges about handling this type of data.

## Ethical Considerations

### Compliance with ethical guidelines

The research was approved by the Local Ethics Committee of National Magnetic Resonance Research Center (UMRAM)-Bilkent University, Ankara, Turkey. Before participation in the study, informed written consent was taken from all participants.

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### Authors' contributions

Conceptualization and supervision: Hussain A. Jaber, Hadeel K. Aljobouri, and Ilyas Çankaya; Methodology: Hussain A. Jaber and Hadeel K. Aljobouri; Data collection: Hussain A. Jaber, and Oktay Algin; Data analysis: Hussain A. Jaber and Hadeel K. Aljobouri; Investigation and writing: All authors.

### Conflict of interest

The authors declared no conflict of interest.

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