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# Towards Structured and Standardized MRI Data Archive - Development of a Tool for DICOM File Arrangement in Java

## Master Thesis

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# Abstract

To be able to communicate with medical equipment manufactured by different vendors, the vast majority of systems today uses the Digital Imaging and Communications in Medicine (DICOM) standard. Although the information of the modality data elements can be made available through specific programs, there are still limitations for the immediate use. Therefore, in this thesis a tool is introduced which consists of two function groups. The first one creates a text file with all the extracted DICOM header information sorted in subgroups and the second function stores the data separately depending the image series in subfolders for a standardized environment in the archive. Furthermore, two examples of images series of a fetal brain examination are demonstrated to show the result after application of the software. In future work, the tool could be integrated in the scanner for the enhancement of the online to offline operation to make the data processing faster and more efficient.

# Table of Contents

# List of Abbreviations

| | |
|---|---|
| *ACR* | *American College of Radiology* |
| *CT* | *Computed Tomography* |
| *DICOM* | *Digital Imaging and Communications in Medicine* |
| *ECG* | *Electrocardiogram* |
| *FID* | *Free Induction Decay* |
| *FT* | *Fourier Transform* |
| *JDK* | *Java Development Kit* |
| *JPEG* | *Joint Photographic Experts Group* |
| *JRE* | *Java Runtime Environment* |
| *MRI* | *Magnetic Resonance Imaging* |
| *NEMA* | *National Electrical Manufactures* |
| *PACS* | *Picture Archiving and Communication System* |
| *PET* | *Positron Emission Tomography* |
| *RF* | *Radio Frequency* |
| *SPECT* | *Single Photon Emission Computed Tomography* |
| *TIFF* | *Tagged Image File Format* |

# 1. Introduction

This thesis is written in the field of Clinical Science of the company Royal Philips. “Royal Philips is a leading health technology company focused on improving people's health and enabling better outcomes across the health continuum from healthy living and prevention, to diagnosis, treatment and home care. Philips leverages advanced technology and deep clinical and consumer insights to deliver integrated solutions. Headquartered in the Netherlands, the company is a leader in diagnostic imaging, image-guided therapy, patient monitoring and health informatics, as well as in consumer health and home care. Philips generated 2018 sales of EUR 18.1 billion and employs approximately 77,000 employees with sales and services in more than 100 countries” [1]. Since the introduction of computed tomography as the first digital imaging method in medicine, the importance of digital medical image processing has steadily increased. At the latest with the emergence of the idea of digital archiving of images (PACS) and electronic image distribution in hospitals, the need arose to be able to exchange digital images between devices from different manufacturers. DICOM was adopted in 1993 and has been continuously expanded ever since. Since 1995 DICOM has also been accepted as a formal standard in Europe (MEDICOM, ENV 12052) [2]. This standard has developed into an indispensable component for the integration of digital image processing systems in medicine. DICOM offers solutions for a variety of communication applications - in the network as well as offline. A DICOM file consists of a list of data elements that contain a variety of image-related information:

- Information about the patient, e.g. name, date of birth and identification number,
- information on modality and recording, e.g. instrument parameters, calibration, radiation dose and contrast agent administration, and
- Image information, such as resolution and windowing.

The DICOM Standard defines for each modality exactly which data elements are prescribed, which are optionally and which are prescribed under certain conditions (e.g. only with contrast medium application). All this information is included when exported from the MRI system and can be made available through specific programs such as the Philips DICOM Viewer. However, this availability is limited and not accessible by many other dedicated programs, especially in the fields of pediatrics or neurology. This leads to a large limitation for the immediate use of the exported DICOM files in a clinical environment and poses therefor the following challenges. When exporting data from the scanner all data are saved almost randomly in one large folder. These are arranged neither in chronological order nor in sequential order. Furthermore, the file names do not reflect imaging information like the image series or information about the data structure. Another concern is that new subfolders are created as soon as the image number succeeds 2048, which leads to a disorganized folder structure. In addition, parameters of the imaging techniques like the pulse sequences are not directly available and have to be displayed by the mentioned tools. In clinical environment, it would be of great benefit to have direct use of the exported DICOM files. It would smooth the “online to offline” research activities, thus from experiments on the scanner to processing on data. In consideration of the presented limitations, the objective for this work is to split the exported DICOM files, so that:

- the data names reflect the basic structure and imaging information like the image series,
- the data can be easily accessed (i.e. loaded and processed) by another software.

Furthermore, the goal is to extract the corresponding DICOM header information, so that:

- important parameters are saved in a separate file,
- basic information with respect to imaging technique and scan protocol are directly available and can be further used for comparison, investigation, publication and citation.

Part of the challenge is to create a tool, which can also deal with the compatibility of various DICOM files of different software release versions (R3, R4).

The remainder of this thesis is organized in the following way. Chapter 2 introduces the reader to the functionality of magnetic resonance imaging and to the DICOM standard. It is described how the standard is used by hospital equipment to store and exchange digital images and associated information. Chapter 3 gives an overview about the programing language Java and a workflow chart is used to illustrate the two functionality groups of the created tool. Chapter 4 presents the tool and the distinctions to other DICOM processing programs. In addition, the two examples diffusion and T2-weighting DICOM image series are shown. The discussion of the results and an outlook of future work is subject of chapter 5. Chapter 6 concludes the work of the project presented in this thesis. In the appendix the source code and the entire list of the parameters to be extracted is given.

# 2. Theoretical Framework

Magnetic Resonance Imaging (MRI) is one of the established imaging methods in clinical routine, which is used primarily in medical diagnostics [3]. The generated data is stored as so-called DICOM files and used for the exchange of information in medical image data management. The physical and medical processes required for the development of these medical images are presented and explained in this chapter.

## 2.1 Magnetic Resonance Imaging

MRI is used in medical diagnostics to visualize the structure and function of tissues and organs in the body. Sectional images of the human or animal body are generated which allow an assessment of the organs and many pathological organ changes. No X-rays or other ionizing radiation is generated or used in the system [4]. In general, all atomic nuclei in the body rotate around their own axis. This angular momentum is also called nuclear spin. Due to their own rotation, these nuclei generate a minimal magnetic field (Fig. 1). Hydrogen nuclei are particularly important here, as they occur most frequently in the body. The magnetic orientation of the hydrogen nuclei is purely random under natural circumstances (Fig. 2). If, however, a strong magnetic field is applied to the body from the outside, then these atomic nuclei all arrange themselves in the same direction, namely in the longitudinal direction of the body (Fig. 3) [5].

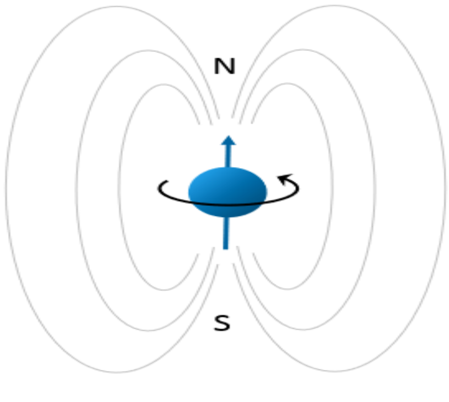



Fig. 1: Atomic nuclei have a spin and are magnetic [16].

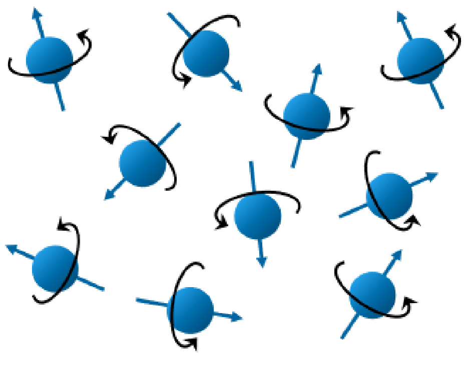


Fig. 2: Atomic nuclei spinning randomly in the tissue [16].

By briefly applying an additional high-frequency alternating field in the radio frequency range, this magnetization can be deflected from the direction of the static field, i.e. partially or completely converted into a transverse magnetization. The transverse magnetization begins immediately to precede the field direction of the static magnetic field, i.e. the magnetization direction rotates. This motion is called Larmor precession and can be observed mechanically analogously on a gyroscope, if its axis of rotation is not vertical, but performs a precession around the vertical (Fig. 4) [3]. Both for excitation and for observation of the signal, a resonance condition must be fulfilled.

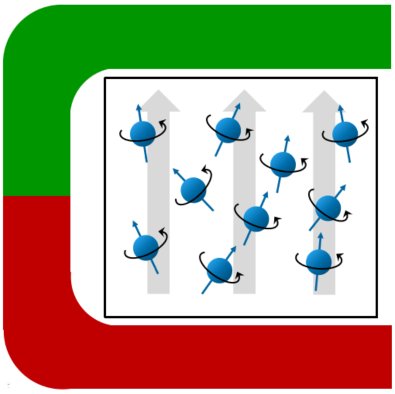


Fig. 3: The application of a strong magnetic field makes all the nuclei align in the same direction [16].

Fig. 4: Gyroscope performing a precession around the vertical [16].

Like the rotation of the magnet in the dynamo in a coil (receiver circuit), this precession movement of the tissue magnetization induces an electrical voltage and can thus be detected. Its amplitude is proportional to the transverse magnetization [6]. After switching off the high-frequency alternating field, the transverse magnetization decreases again, so that the spins again align themselves parallel to the static magnetic field. For this so-called relaxation they need a characteristic decay time. This is dependent on the chemical compound and the molecular environment in which the preceding hydrogen nucleus is located. Therefore, the different tissue types differ characteristically in their signal, which leads to different signal strengths (brightness) in the resulting image as can for example be seen in Figure 5 and Figure 6 [6].

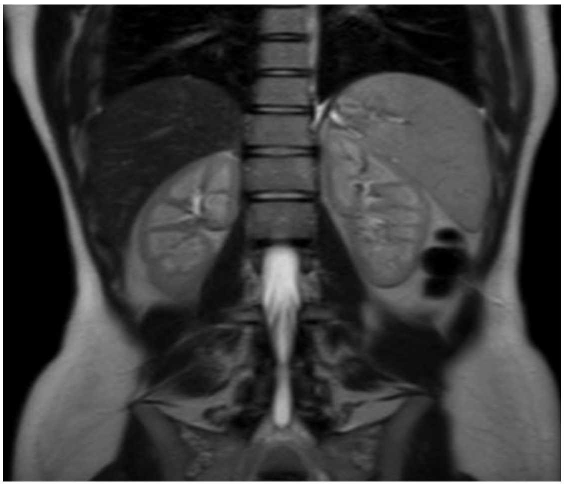


Fig. 5: A typical MR image of the abdomen [6].

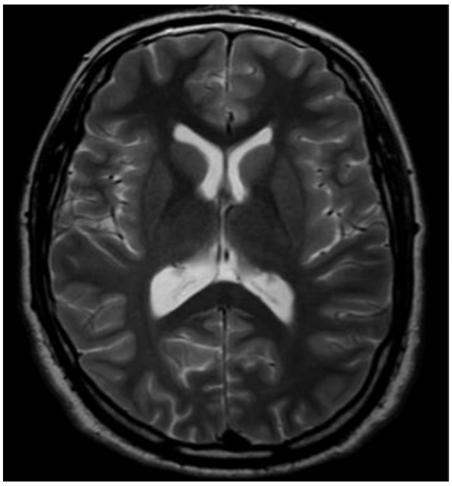


Fig. 6: A typicial MR image of the head [6].

The intensity of magnetic resonance signals is a function of several parameters, including relaxation times $T_1$ and $T_2$, proton density, chemical shift and motion. These parameters are set in the pulse sequence [6]. Such an electromagnetic pulse sequence is a pre-selected set of radio frequency and gradient pulses that are repeated many times during a scan. In the short time interval between the pulses, signals are received and automatically evaluated by a computer (depending on the amplitude and shape of the gradient waves one receive different signals), and images are calculated [6]. Virtually all MR pulse sequences can be separated into two functional parts – the spin preparation, which means the manipulation of the MR signal characteristics through the use of radio frequency pulses or magnetic field gradients and the signal production, which describes components necessary to generate the signal and encode this signal with spatial information (Fig. 7) [6].

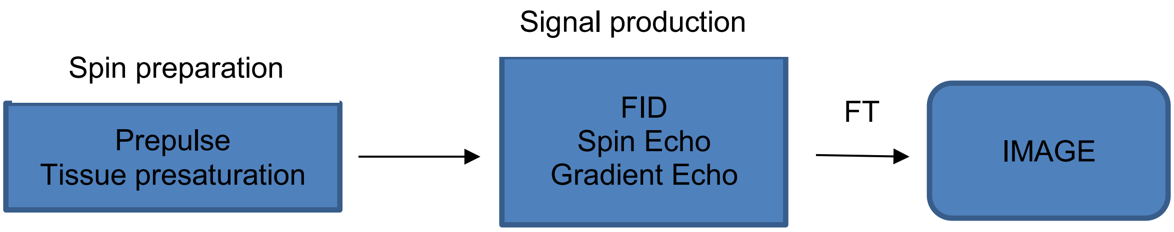



Fig. 7: A pulse sequence separated into two functional elements: signal production and spin preparation.

An MRI system (Fig. 8) includes a combination of a static magnetic field, local variations of this magnetic field to encode spatial information on the nuclei within a tissue sample and radio frequency pulses, applied through a pulse generation system, to generate a signal. The detection is accomplished through a receiver system detecting the re-emitted energy and transporting this signal to a computer system for digital processing and image display [6].

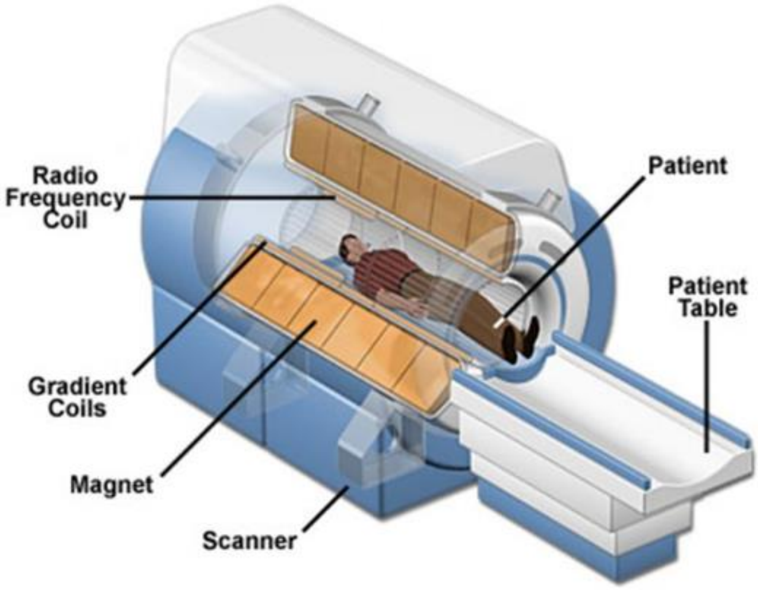



Fig. 8: An MRI scanner cutaway [5].

The following components are necessary for an MR imaging system:

1. Magnet for generating the static magnetic field.
2. Magnetic field gradient system, consisting of gradient amplifier and coils.
3. RF amplifier and RF transmit coil for production of pulses to excite the nuclei.
4. RF receive coil and amplifier to detect the re-emitted signal from the nuclei.
5. Acquisition and control system for digital signal and image processing.
6. Physiology hardware to measure a patient's ECG and respiratory cycle.
7. Reconstruction system.
8. A viewing console for display of the images and for operator input of parameters.
9. Archiving system.
10. Magnetic shielding to minimize the effect of fringes.
11. RF shielding to protect the system from external RF interferences and vice versa.
12. Patient table for positioning the patient in the magnet during an examination.
13. Patient monitoring equipment to monitor the patient during an examination [6].

## 2.2 DICOM Standard

Digital Imaging and Communications in Medicine (DICOM) is an open standard for the storage and exchange of information in medical image data management [7]. In the process of the development of digital imaging systems at the beginning of the 1970s, driven mainly by the development of the computer tomography scanner by Godfrey Hounsfield, the need grew to be able to exchange image data between systems of different manufacturers. In 1982, the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) founded a working group to define the exchange of digital imaging information. The first version of the ACR/NEMA standard was published in 1985, a second in 1988, and version 3.0 of 1993 changed the name from "ACR-NEMA" to DICOM. Since then, new revisions of the standard have appeared at regular intervals. The 2019B standard is the currently available one [7]. The information of the medical image data management can be, for example, digital images, additional information such as segmentations, surface definitions or image registrations. DICOM standardizes both the format for storing the data and the communication protocol for its exchange [8]. Almost all manufacturers of medical imaging or image processing systems such as digital x-ray, magnetic resonance imaging, computed tomography or sonography implement the DICOM standard in their products. This enables interoperability between systems from different manufacturers in the clinical environment. DICOM is also the basis for digital image archiving in practices and hospitals. DICOM contains not only data fields (e.g. information about images, findings, patients, studies, series) but also the syntax and semantics of commands and messages [7]. Furthermore, the standard defines regulations for the description of DICOM-compatible devices and software, since for every DICOM-compatible device an exact description of the system capability must be available and published, the so-called DICOM Conformance Statement. A DICOM dataset serves as a container, which, in addition to one or more object definitions, can also contain meta information such as patient name, admission date, device parameters or physician name. The object definitions can be image data, geometric or mathematical information and treatment-specific information. DICOM stores or transfers images lossless, based on the TIFF format and the JPEG standard. The different compression methods are defined in their own transfer syntaxes. The DICOM standard also allows one to define its own so-called private objects, modules or attributes. However, this proprietary information is normally no longer compatible with implementations of other manufacturers [8]. Several working groups are still continuously expanding nowadays the DICOM standard in order to counter the continuous development of medical, hardware and software technology. There are 32 working groups (as of Jan. 2019) that extend DICOM by various subareas [7]. Members of the working groups are employees of medical technology manufacturers, clinics, universities and other research institutions. As an example, the current developments of the working groups Base Standard and Radiotherapy deal with the introduction of a new definition of workflows within the different domains of a hospital and the necessary introduction of new DICOM objects [7]. Further developments are added to the standard by so-called supplements. These are first written by one or more working groups and then submitted to the Base Standard working group for review. If the extension seems useful, a number is assigned to the supplement. As soon as the working groups have finalized their additions, they are submitted to the voting NEMA members (DICOM Voting Members) for voting. After a positive vote, the information within the addendum becomes valid and is incorporated into the subsequent version of the DICOM standard. Changes to the standard or errors in the documents can be submitted to the various working groups by means of a change request and are also submitted to the voting members by the Base Standard working group. Elements removed from the DICOM standard should no longer be considered for new implementations. In general, however, for reasons of downward compatibility, only elements that conflict with other concepts of the standard or have never or only rarely been implemented are removed [7].

### 2.2.1 DICOM Parameter

DICOM differs from other image formats in that it groups information into data sets. A DICOM file consists of a header and image records that are grouped into a single file. As Figure 9 indicates, the information within the header is organized as a constant and standardized set of tags. By extracting data from these tags, important information about patient demography, study parameters, etc. can be accessed [9].The first few information packages in a DICOM image file form the "header". It stores demographic information about the patient, acquisition parameters for image analysis, image dimensions, matrix size, color space, and a variety of additional non-intensity information that the computer needs to display the image correctly. The header is followed by a single attribute that contains all pixel intensity data for the image. This data is stored as a long series of 0s and 1s that can be reconstructed as an image using the information from the header. This attribute can contain information about a single image, multiple images of a study, or a cine loop, depending on the modality the image has generated. The header data information is encoded within the DICOM file so that it cannot be accidentally separated from the image data. If the header is separated from the image data, the computer does not know which image analysis was performed or to whom it belongs, and it cannot display the image correctly, leading to a possible medical-legal situation. The information inside the header is organized as a constant and standardized set of tags. These tags are organized into groups of data elements. For example, the group "0010" contains patient information and is 92 bits long. It contains the name of the patient in tag "0010-0010", the identification number of the patient in tag "0010-0020", the date of birth in tag "0010-0030", and so on. The group "0018" also contains information about the acquisition. It is 482 bits long and contains several elements that transmit the MRI recording parameters. The "0028" group encodes the image display and is responsible for displaying the image on a monitor. A list of all tags can be found in the appendix. The analysis of the DICOM header can also provide valuable information about the image analysis itself. For example, if a radiologist encounters a high-quality MRI image and wants to replicate the MRI pulse sequence on his MRI scanner, he can easily access all relevant parameters via the DICOM header [8].

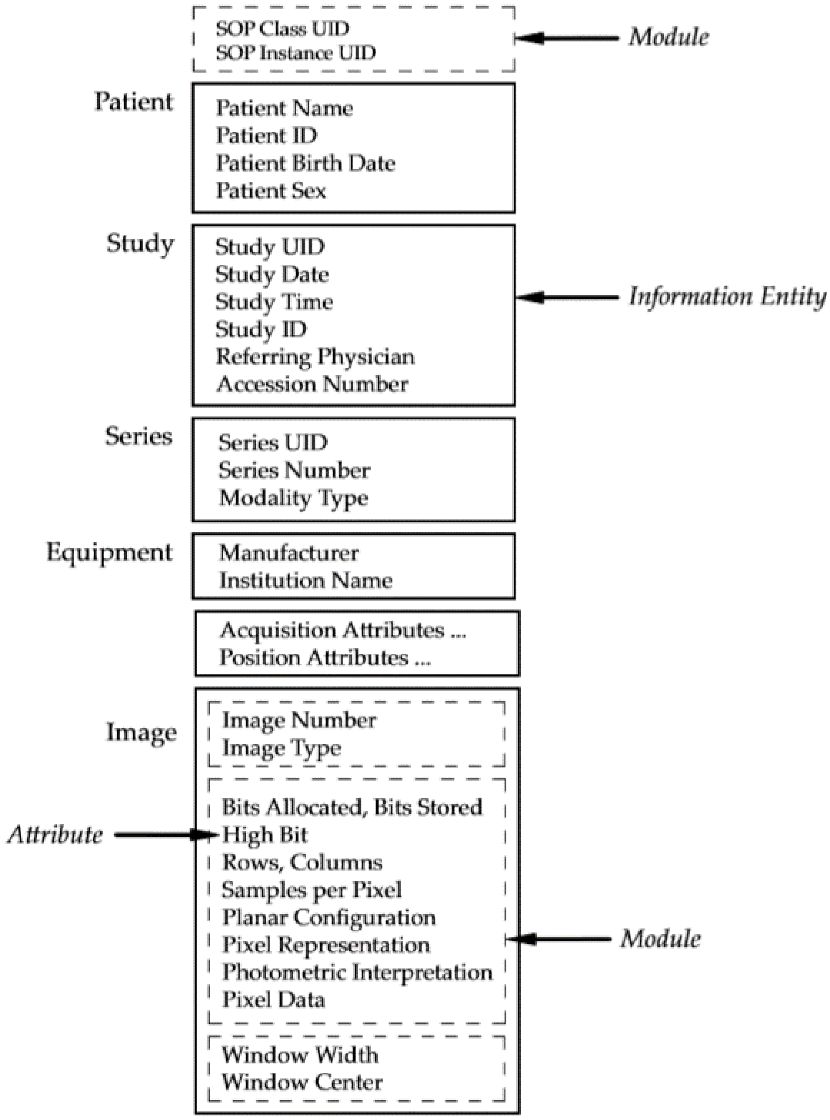



Fig. 9: The structure of the DICOM header information [8].

### 2.2.2 Archive and Post-Processing

In medicine, a Picture Archiving and Communication System (PACS) is an image archiving and communication system based on digital computers and networks [9]. The first PACS developments began in the 1970s. PACS capture digital image data of all modalities in radiology and nuclear medicine. A PACS consists of the PACS server, to which a short-term and a long-term archive are connected. The server sends data to viewing and post-processing computers, but also communicates with the connected imaging modalities (Fig. 10). In most cases, there is also a connection to the radiology information system. Larger PACS installations can also consist of several servers and archives that may be coupled over long distances [9].

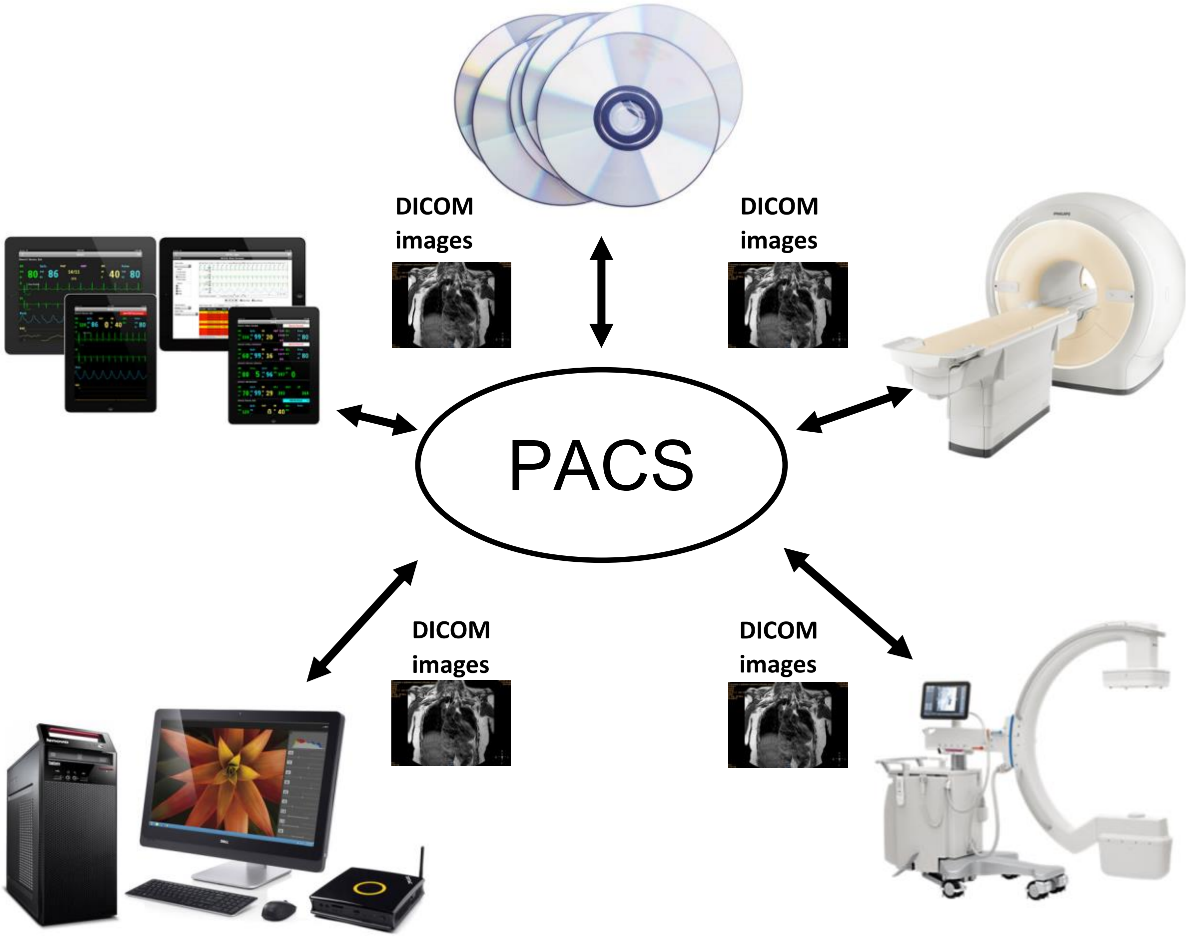



Fig. 10: A picture archiving and communication system (PACS) provides access to images from multiple modalities [1].

In order to enable the integration of the different components with each other and the embedding of PACS in hospital information systems, the DICOM standard is used among other things. Uniform DICOM communication means that PACS servers and imaging devices can be used independently of manufacturers, and the connection of a device becomes simple and cost-effective. Modern large-scale medical imaging equipment such as CTs, PET/CTs, MRs or SPECT cameras consistently deliver image data in digital form in accordance with the DICOM-3 standard. If images present in film form have to be captured, they are digitized with the aid of a scanner, which receives the information for the DICOM header from the radiology information system. The image is then transferred to the PACS. Especially with older devices, the standard was sometimes not maintained or not all fields were filled with information, which led to communication or memory errors. Often the possibility to store the image data in the

DICOM standard is only offered optionally connected with high costs by the device manufacturer [9]. The core of each PACS is the PACS server. All modalities of a PACS environment deliver their images here and they are also stored here. In mostly every hospital in the industrialized world today, all radiological image data is stored in the PACS. In a typical 400-bed hospital, this data volume amounts to approximately three to five terabytes per year [9]. The radiology archive of a university hospital can therefore be several 100 terabytes in size. However, the exact size and quantity of the images produced varies depending on the type and number of connected modalities. For example, a modern 64-line CT produces a multiple of the images output by an older 4-line CT. The data volume of a mammography image is also considerably larger than that of a conventional X-ray image. In the memory of the PACS archive, the image data is sometimes no longer available in the DICOM data structure. In some systems, the PACS server receives the DICOM data, separates the header and image data and stores both information - sometimes compressed - in a common database. In addition to the information of the DICOM header, further information such as changes or displacements of the image are also stored there. If the images are retrieved from a remote station, they are reconverted into the DICOM format for dispatch. In contrast to image documentation on paper or film carriers, PACS works with digital image data. This results in comprehensive possibilities for increasing the functionality and efficiency of workflows. Thanks to digital storage, the quality of the images remains unchanged for many years. With projection radiographic methods, digital recording enables a higher range of contrast. Images are therefore more informative, repeat images after incorrect exposures less frequent than with film radiography. For sectional image procedures, there are extended possibilities for viewing and reporting. For example, a series of cuts can be displayed as an animation, converted into a 3D model at any time or post-processed with special evaluation software. PACS also simplifies the documentation of motion images with ultrasound. A major advantage is the simultaneous availability of images at several locations via a computer network, which completely eliminates the logistical effort required for conventional image transport. Since the images can also be reproduced over longer distances, the assessment can be carried out at short notice [9].

# 3. Methodology

In this chapter the concept and functionalities of the developed tool are described. The goal is to arrange DICOM files, provided by imaging systems, clearly displayed and sorted. First of all, Java is chosen as the programming language. It is especially suitable for beginners as it is both easy to understand and easy to learn. Second, ImageJ is installed to facilitate the use of DICOM Tools for reading and analyzing the DICOM header tags. In general, two function groups are developed in the tool. The first one is used to extract all the needed information from the DICOM headers. The second one restructures all the files in new subfolders. These two function groups are described in detail in the following sections. A workflow chart demonstrating the entire process is presented in Figure 12.

## 3.1 Java and Eclipse

The programming language used for the realization is Java. Java is an object-oriented programming language and is a component of Java technology - which basically consists of the Java Development Tool (JDK) for creating Java programs and the Java Runtime Environment (JRE) for executing them. The runtime environment itself includes the virtual machine (JVM) and the supplied libraries [10]. Different functions and commands can be taken from these libraries and do not need to be redefined, which simplifies working in Java. Another advantage of the programming language is its system independence. Java runs on a mobile phone, a workstation PC or an enterprise class server regardless of the type of operating system or hardware. Because interfaces to all environmental systems can be developed, Java can be integrated into almost any existing IT infrastructure, which makes it a very flexible programming language [10]. When programming Java code there are different ways to write executable programs. One way would be to use a text editor to develop the source code and then compile it. If the range of functions and the expected source code is only small, this is a fast and uncomplicated possibility. Since the presented program contains a high number of functions and classes, the use of a development environment is essential. The expected errors can be discovered faster and more uncomplicated with a development environment and can be found and eliminated with an integrated debugger if necessary. There are different development environments, some are free, and others have to be purchased. Furthermore, they differ in the scope of functions. For this work, Eclipse is chosen. Eclipse is an open source development environment that can be used to program different languages [11]. The special feature is the extensibility of Eclipse JDT. There are a large number of freely available, but also commercial extensions. Eclipse JDT is delivered with the following components for Java development:

- Text Editor
- Compiler
- Linker
- Debugger

Having all components combined it makes it very handy and easy for the user to write and run programs. Furthermore, during programming, the development environment indicates possible errors and displays them graphically, which is another advantage. The user interface is organized and provides a good overview of the current project (Fig. 11). The function bar can be individually equipped with further functions and their position can be freely selected. Eclipse JDT can be used for almost any project due to its great extensibility.

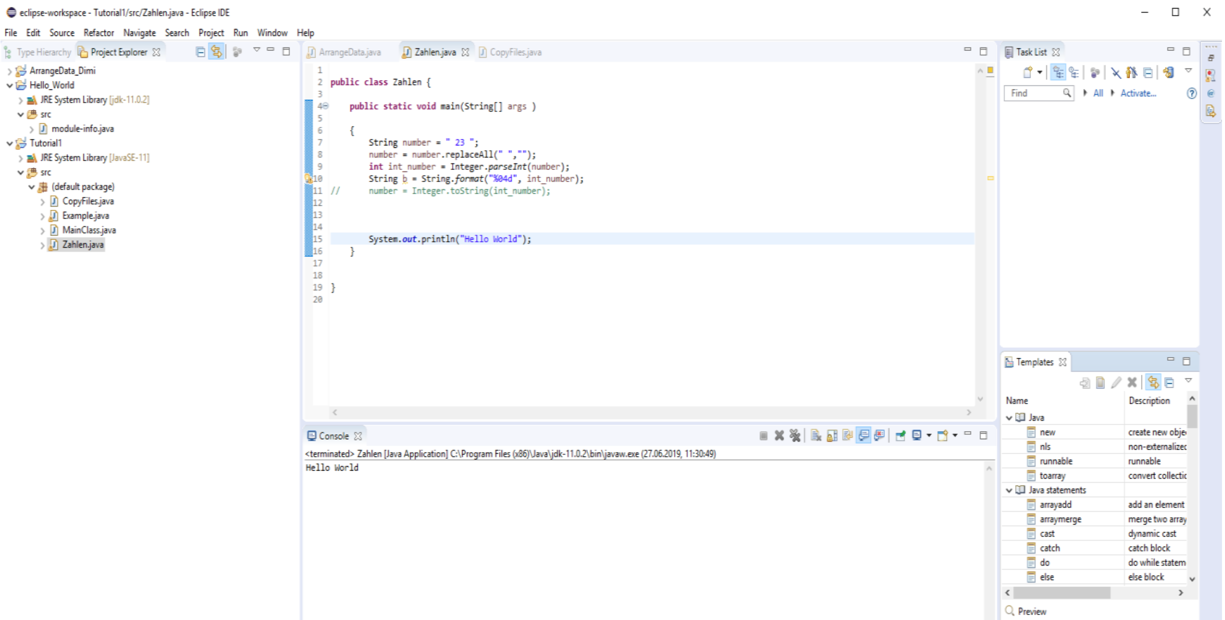


Fig. 11: The Eclipse JDT User Interface.

For this work, ImageJ as an image processing program is essential to process DICOM files in Java application. With the plugin, it is possible to decode DICOM files and use its data. In a later section, ImageJ will be described in more detail.

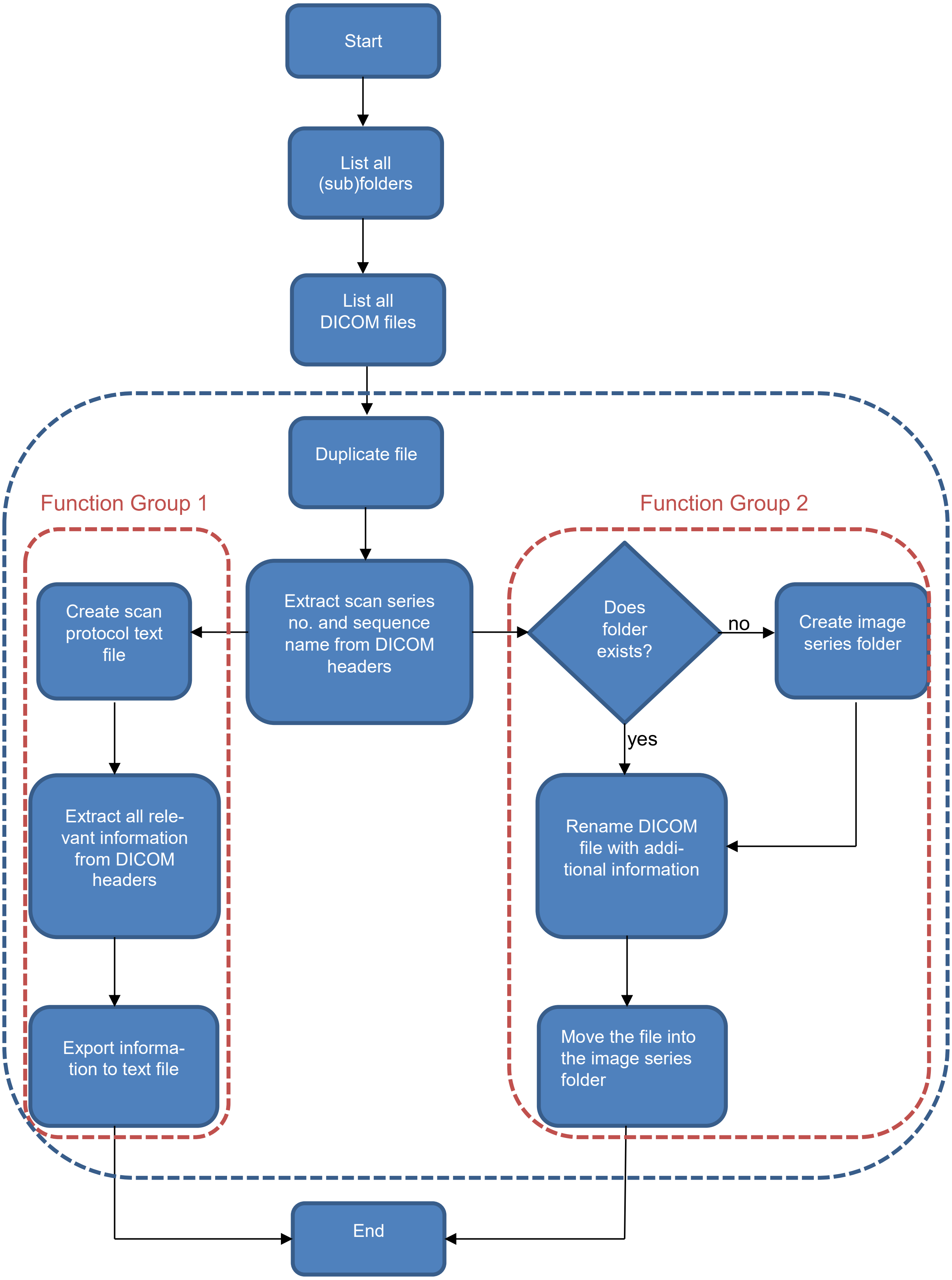



Fig. 12: The workflow chart as the basis of the development of the program.

## 3.2 Function Group 1: DICOM Header Extraction

At the start of the program, as displayed in Figure 13, the tool calls a window to ask the user to select a folder, which contains DICOM files. Once done, a loop function is executed to identify all the DICOM files. This is repeated until all subfolders are covered. A subfolder may exist if the number of the DICOM files in a (sub)folder exceeds 2048. This is done before the execution of the two main function groups of the program. Conditional commands are used in the tool. These instructions are program sections that are only executed under a certain condition. A branch determines which of two program sections is executed depending on a condition. For example, a conditional statement is used to check whether the existing file has a DICOM name. If this is not the case, the file will not be processed further and remains in the folder as it is. The selected DICOM file is then to be duplicated. The original file remains where it is and the duplicate is used for the further program execution. In Function Group 1, the functionality of the ImageJ plugin is used to extract the needed parameters from the DICOM headers. Especially the scan series number and the sequence name are used in the following. A scan protocol file in text format with the identical name as the image series is created. Then the following parameters are extracted from the DICOM headers of the files for each image series:

- Hardware and Software
- Series and Image
- Exam Card
- Sequence Type
- Geometry
- Contrast
- Motion and Physiology
- Dynamics
- Post Processing
- Spectroscopy
- Safety, SAR and Noise
- Orientation and Position
- Coil

In a last step of this function group, the above sorted information is exported into the text file. After a complete run of the program as many text files as subfolders are created in the main folder.

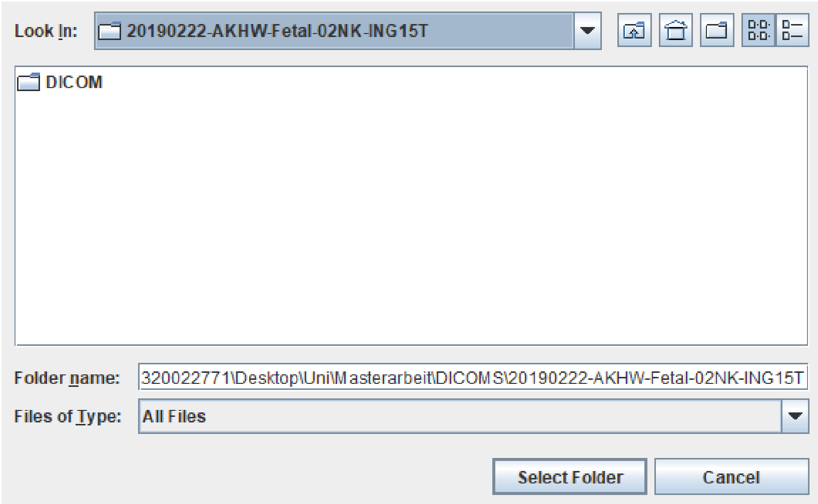



Fig. 13: The window, which opens after the start of the program.

## 3.3 Function Group 2: Data Restructuring

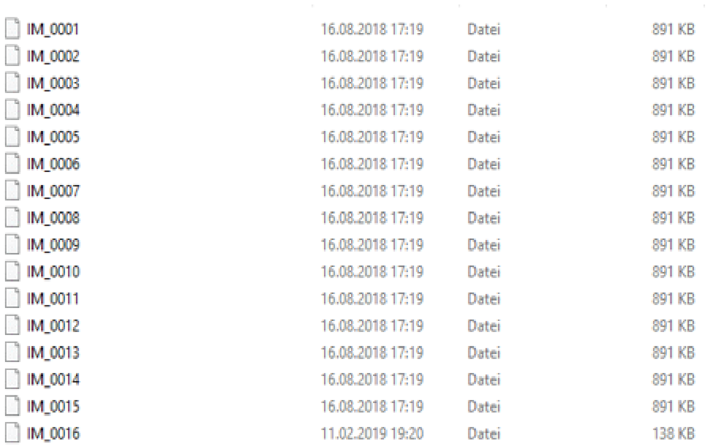
This is followed by the second main function of the program, which is, according to the extracted DICOM header information, to create subfolders for each individual image series and to restructure all corresponding DICOM files. The first steps are as described above. After extracting, the scan series number and the sequence name from the DICOM headers a name and a new path has to be created. For this purpose, the conditional statement is used to check whether a path already exists and therefor whether this folder already exists. If not, it is created this time. The next step is to move the DICOM file to that image series subfolder. Further extracted parameters help to rename the file in such a way that it gets a unique name in order not to be mistaken for other files.

# 4. Results

In the previous chapter, requirements for the program were developed and specified using a workflow chart. Based on these requirements, this chapter will use software engineering methods to create this program, which will be presented in a before-and-after comparison. A comparison with other DICOM Viewer programs is presented in the following section.

## 4.1 Execution of the developed Program

Before the application of the program developed in Java, the DICOM files are only sorted by name and not by scan series in the folder.



| | | | |
|---|---|---|---|
| IM_0001 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0002 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0003 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0004 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0005 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0006 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0007 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0008 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0009 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0010 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0011 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0012 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0013 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0014 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0015 | 16.08.2018 17:19 | Datei | 891 KB |
| IM_0016 | 11.02.2019 19:20 | Datei | 138 KB |

Fig. 14: The DICOM data files of a prostate examination are randomly stored in the folder.

A new data structure exists after application of the program as can be seen in Figure 15. New subfolders are created with the name of the respective image series. The respective subfolders contain the corresponding sorted DICOM files with a new name, consisting of the original name, series number, image plane number, MR series number of dynamic scans and instance number.

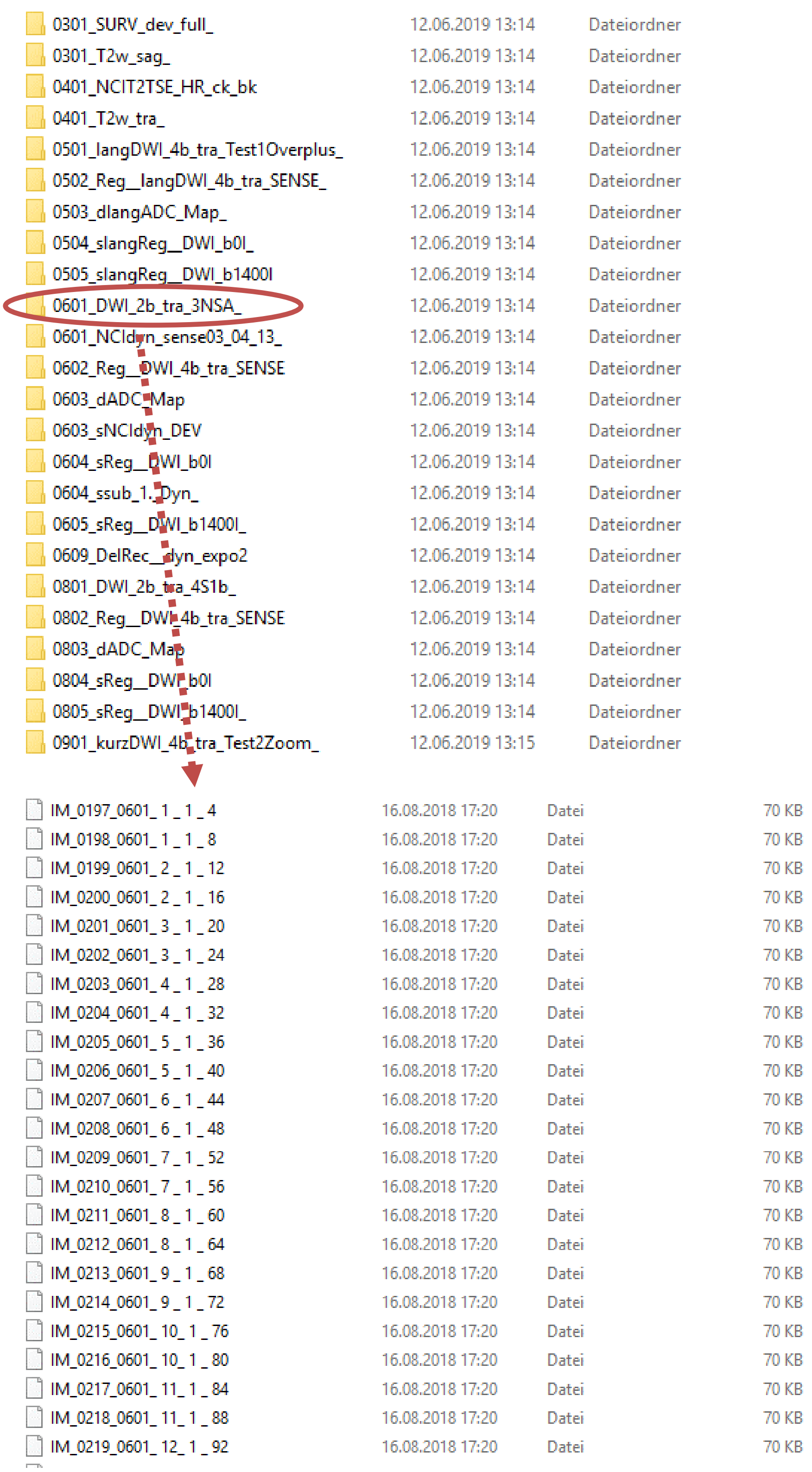
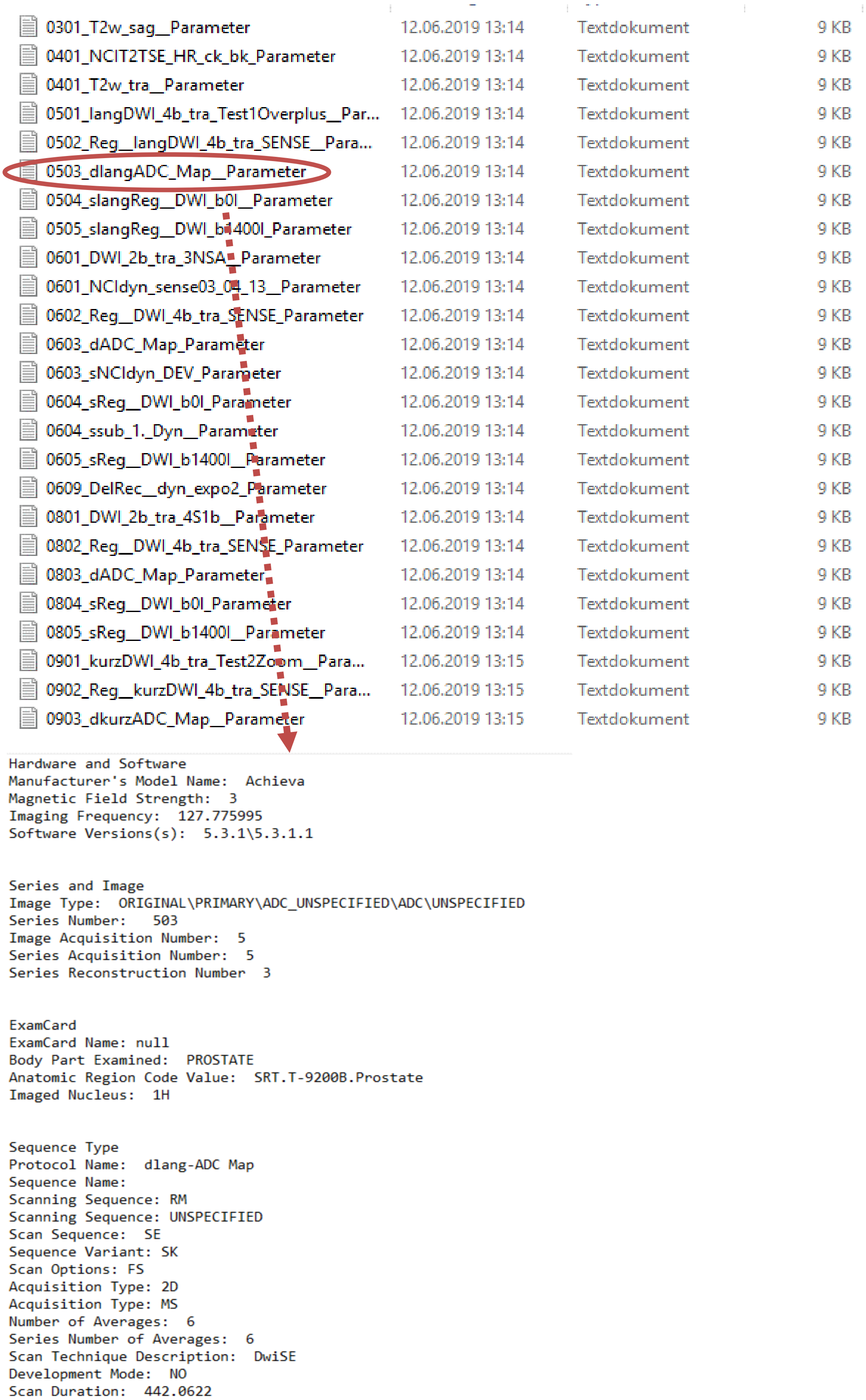



Fig. 15: After using the created program, the DICOM files are sorted and structured in subfolders.

In addition, apart from the new subfolders, there are just as many new text files in the folder, which are also named after the image series. In the text files, all important scan protocol parameters of the respective image series are stored.



| | | | |
|---|---|---|---|
| 0301_T2w_sag__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0401_NCIT2TSE_HR_ck_bk_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0401_T2w_tra__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0501_langDWI_4b_tra_Test1Overplus__Par... | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0502_Reg__langDWI_4b_tra_SENSE__Para... | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0503_dlangADC_Map__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0504_slangReg__DWI_b0l__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0505_slangReg__DWI_b1400l_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0601_DWI_2b_tra_3NSA__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0601_NCIdyn_sense03_04_13__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0602_Reg__DWI_4b_tra_SENSE_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0603_dADC_Map_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0603_sNCIdyn_DEV_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0604_sReg__DWI_b0l_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0604_ssub_1._Dyn__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0605_sReg__DWI_b1400l__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0609_DelRec__dyn_expo2_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0801_DWI_2b_tra_4S1b__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0802_Reg__DWI_4b_tra_SENSE_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0803_dADC_Map_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0804_sReg__DWI_b0l_Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0805_sReg__DWI_b1400l__Parameter | 12.06.2019 13:14 | Textdokument | 9 KB |
| 0901_kurzDWI_4b_tra_Test2Zoom__Para... | 12.06.2019 13:15 | Textdokument | 9 KB |
| 0902_Reg__kurzDWI_4b_tra_SENSE__Para... | 12.06.2019 13:15 | Textdokument | 9 KB |
| 0903_dkurzADC_Map__Parameter | 12.06.2019 13:15 | Textdokument | 9 KB |

```
Hardware and Software
Manufacturer's Model Name:  Achieva
Magnetic Field Strength:  3
Imaging Frequency:  127.775995
Software Versions(s):  5.3.1\5.3.1.1


Series and Image
Image Type:  ORIGINAL\PRIMARY\ADC_UNSPECIFIED\ADC\UNSPECIFIED
Series Number:   503
Image Acquisition Number:  5
Series Acquisition Number:  5
Series Reconstruction Number  3


ExamCard
ExamCard Name: null
Body Part Examined:  PROSTATE
Anatomic Region Code Value:  SRT.T-9200B.Prostate
Imaged Nucleus:  1H


Sequence Type
Protocol Name:  dlang-ADC Map
Sequence Name:
Scanning Sequence: RM
Scanning Sequence: UNSPECIFIED
Scan Sequence:  SE
Sequence Variant: SK
Scan Options: FS
Acquisition Type: 2D
Acquisition Type: MS
Number of Averages:  6
Series Number of Averages:  6
Scan Technique Description:  DwiSE
Development Mode:  NO
Scan Duration:  442.0622
```

Fig. 16: The folder contains a text file with the sorted DICOM parameters for each image series.

## 4.2 Comparison with other Programs

DICOM files can be read and viewed in many different ways. In the following, two important programs are shown and compared with the program developed in this thesis. One is the program ImageJ. ImageJ is a cross-platform image processing program written in Java. It is often used for medical and scientific image analysis, for example the measurement of structures on microscope images [12]. The functionality of the program can be extended by many plugins and so it is a good way to view DICOM files with this program. The program and the source code are in the public domain (open source) and may therefore be freely copied and modified by anyone or extended by plugins. In addition, the API of ImageJ is designed in such a way that ImageJ itself can be integrated into other programs as an image processing library, as for example in this work (see code in the appendix). After opening ImageJ one will see the editing bar and can open the DICOM file to be viewed via the menu or by "drag and drop" (Fig. 17). By selecting “Image” and “Information” one can access the DICOM tags (Fig. 18).

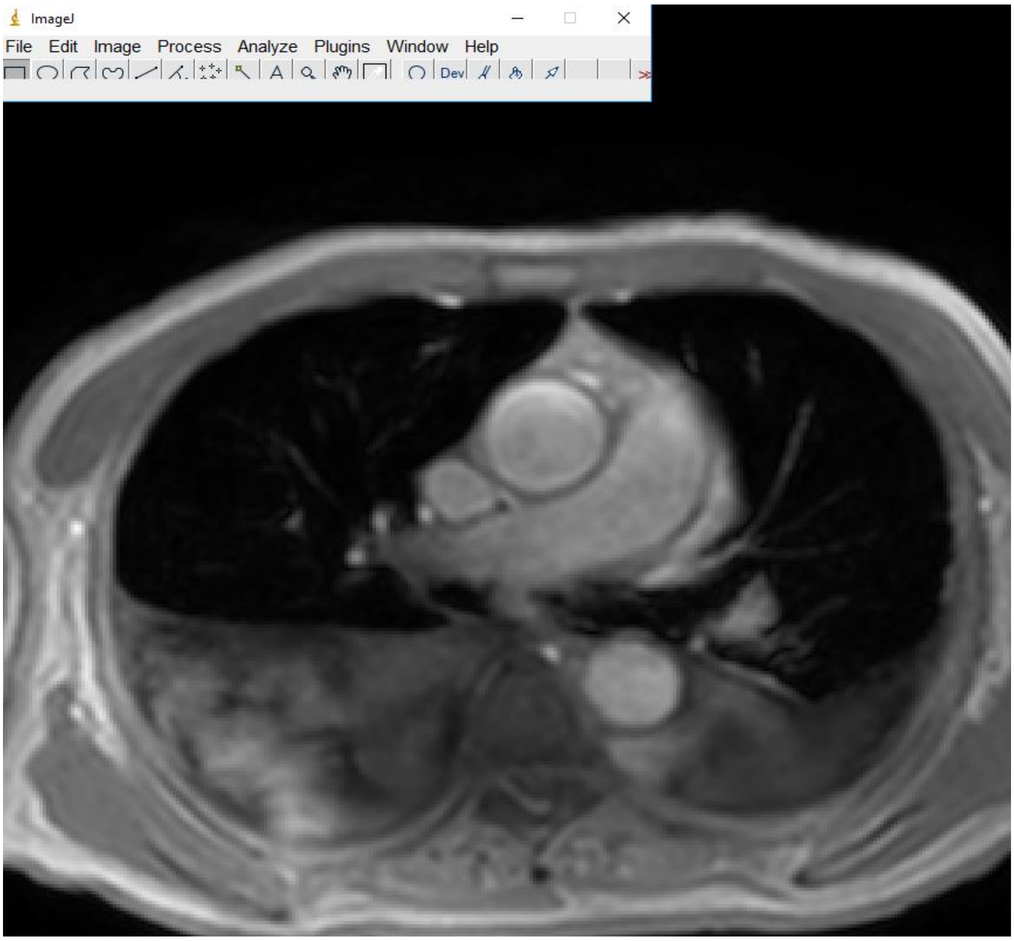



Fig. 17: An MRT sectional image displayed via ImageJ.

```
2005,1406  >---: 1
0008,1115  Referenced Series Sequence:
0008,1150  >Referenced SOP Class UID: 1.2.840.10008.5.1.4.1.1.4.1
0008,1155  >Referenced SOP Instance UID: 1.3.46.670589.11.3052646802.3020511800.1255186120.3481524297
0020,000E  Series Instance UID: 1.3.46.670589.11.2678157720.3824607871.1422907474.2545390752
0020,000D  Study Instance UID: 1.3.46.670589.11.3579141627.2603925190.1187316182.2797193397
0008,1115  Referenced Series Sequence:
0008,1150  >Referenced SOP Class UID: 1.2.840.10008.5.1.4.1.1.4.1
0008,1155  >Referenced SOP Instance UID: 1.3.46.670589.11.1332710769.886966374.950650057.634117010
0020,000E  Series Instance UID: 1.3.46.670589.11.3595656534.2655181308.1591032416.652175929
0020,000D  Study Instance UID: 1.3.46.670589.11.3579141627.2603925190.1187316182.2797193397
0008,9123  ---: 1.3.46.670589.11
0008,9205  ---: MONOCHROME
0008,9206  ---: VOLUME
0008,9207  ---: NONE
0008,9208  ---: MIXED
0008,9209  ---: FLOW_ENCODED
0010,0010  Patient's Name: NSS
0010,0020  Patient ID: 1.3.46.670589.11.4127254551.3766128535.432151220.104375514
0010,0030  Patient's Birth Date: 19500101
0010,0040  Patient's Sex: M
0010,1030  Patient's Weight: 65
0018,0015  Body Part Examined:
0018,0022  Scan Options: FC
0018,0023  MR Acquisition Type: 2D
0018,0087  Magnetic Field Strength: 3
```

Fig. 18: The DICOM header information when opened via ImageJ.

Another program to view DICOM data is the DICOM Viewer, an program developed by Philips Medical Systems Nederland B.V., which runs on Windows (Fig. 19). It automatically detects the DICOM file if the DICOM file is located in the root of the drive the Philips Viewer is started from or in the current working folder. A special feature of the DICOM Viewer is that the files are automatically sorted into image series (Fig. 19). In addition, the patient data always appears in the upper left corner and the files can also be edited, for example by changing the contrast. Here one can also access the DICOM tags by selecting the image information (Fig. 21). It can be observed that subfolders are also created in the DICOM Viewer when the DICOM data is uploaded. These are separated according to the different image series. It can be noticed that as many subfolders are created as in the developed tool (Fig. 20). The difference is that via the DICOM Viewer the data cannot be used directly for further processing, but can only be viewed.

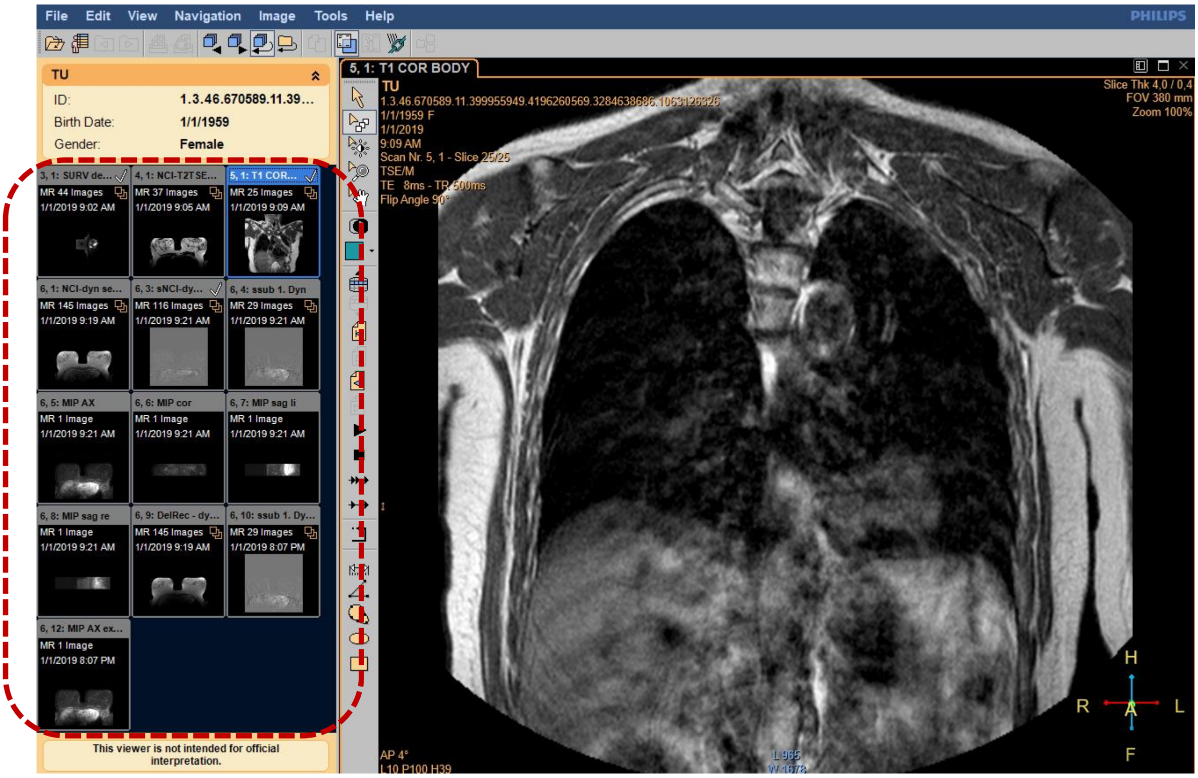
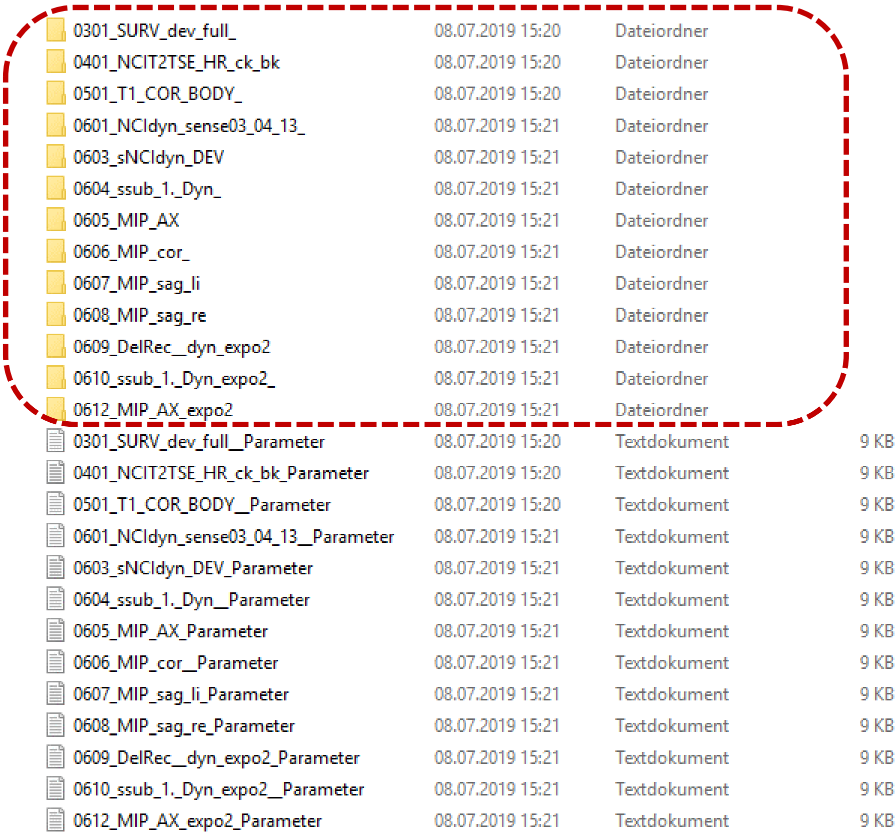



Fig. 19: An MRI sectional image displayed via the DICOM Viewer.



| | | | |
|---|---|---|---|
| 0301_SURV_dev_full_ | 08.07.2019 15:20 | Dateiordner | |
| 0401_NCIT2TSE_HR_ck_bk | 08.07.2019 15:20 | Dateiordner | |
| 0501_T1_COR_BODY_ | 08.07.2019 15:20 | Dateiordner | |
| 0601_NCIdyn_sense03_04_13_ | 08.07.2019 15:21 | Dateiordner | |
| 0603_sNCIdyn_DEV | 08.07.2019 15:21 | Dateiordner | |
| 0604_ssub_1._Dyn_ | 08.07.2019 15:21 | Dateiordner | |
| 0605_MIP_AX | 08.07.2019 15:21 | Dateiordner | |
| 0606_MIP_cor_ | 08.07.2019 15:21 | Dateiordner | |
| 0607_MIP_sag_li | 08.07.2019 15:21 | Dateiordner | |
| 0608_MIP_sag_re | 08.07.2019 15:21 | Dateiordner | |
| 0609_DelRec__dyn_expo2 | 08.07.2019 15:21 | Dateiordner | |
| 0610_ssub_1._Dyn_expo2_ | 08.07.2019 15:21 | Dateiordner | |
| 0612_MIP_AX_expo2 | 08.07.2019 15:21 | Dateiordner | |
| 0301_SURV_dev_full__Parameter | 08.07.2019 15:20 | Textdokument | 9 KB |
| 0401_NCIT2TSE_HR_ck_bk_Parameter | 08.07.2019 15:20 | Textdokument | 9 KB |
| 0501_T1_COR_BODY__Parameter | 08.07.2019 15:20 | Textdokument | 9 KB |
| 0601_NCIdyn_sense03_04_13__Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |
| 0603_sNCIdyn_DEV_Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |
| 0604_ssub_1._Dyn__Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |
| 0605_MIP_AX_Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |
| 0606_MIP_cor__Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |
| 0607_MIP_sag_li_Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |
| 0608_MIP_sag_re_Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |
| 0609_DelRec__dyn_expo2_Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |
| 0610_ssub_1._Dyn_expo2__Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |
| 0612_MIP_AX_expo2_Parameter | 08.07.2019 15:21 | Textdokument | 9 KB |

Fig. 20: The developed tool creates as many subfolders as can be seen in the DICOM Viewer.

| DICOM Information | | |
|---|---|---|
| **Tag** | **Attribute Name** | **Attribute Value** |
| (0008,0102) | Coding Scheme Designator | |
| (0008,1032) | Procedure Code Sequence | Code 5{DICOM_CODE_VALUE{UNDEFIN… |
| (0008,1090) | Manufacturer's Model Name | Achieva |
| (0008,1111) | Referenced Performed Procedure Step Sequence | InstanceReference 9{DICOM_INSTANCE… |
| (0008,1140) | Referenced Image Sequence | ImageReference 2{DICOM_REFERENCE… |
| (0010,0010) | Patient Name | TU |
| (0010,0020) | Patient ID | 1.3.46.670589.11.399955949.4196260569.… |
| (0010,0030) | Date of Birth | 1/1/1959 |
| (0010,0040) | Patient Gender | F |
| (0010,1030) | Patient's Weight | 80 |
| (0018,0015) | Body Part Examined | Breast |
| (0018,0020) | Scanning Sequence | SE |
| (0018,0021) | Sequence Variant | SK |
| (0018,0022) | Scan Options | OTHER |
| (0018,0023) | MR Acquisition Type | 2D |
| (0018,0050) | Slice Thickness | 4 |
| (0018,0080) | Repetition Time | 500,000213623046 |
| (0018,0081) | Echo Time | 8 |
| (0018,0083) | Number of Averages | 1 |
| (0018,0084) | Imaging Frequency | 63,897765 |
| (0018,0085) | Imaged Nucleus | 1H |
| (0018,0086) | Echo Number | 1 |
| (0018,0087) | Magnetic Field Strength | 1.5T |

Fig. 21: The DICOM parameters displayed via the DICOM Viewer.

## 4.3 Examples of DICOM Image Series

In the following, two different DICOM image series from a fetal brain examination in MRI environment are presented and compared. One is the T2-weighted and the other the diffusion-weighted image series:

- 2001_T2_240_140_Head_
- 2301_DWI_HEADneu5mm_.

The T2 weighting is a contrast representation of MRI images in which the repetition time and the echo time are selected in such a way that the tissue examined is differentiated primarily by its T2 relaxation time and less by its T1 relaxation time [5]. In the T2-weighted images, water appears bright due to the large number of protons and the resulting large transverse magnetization, whereas tissues with a low proton density appear dark. Diffusion-weighted MRI is an imaging technique that measures the diffusion movement of water molecules in body tissue and displays it in spatial resolution. It is used to examine the brain, since the diffusion behavior in tissue changes characteristically in some diseases of the central nervous system and the directional dependence of diffusion allows conclusions to be made about the course of the large nerve fiber bundles [13].

Fig. 22: The T2-weighted MRI image of the fetus.

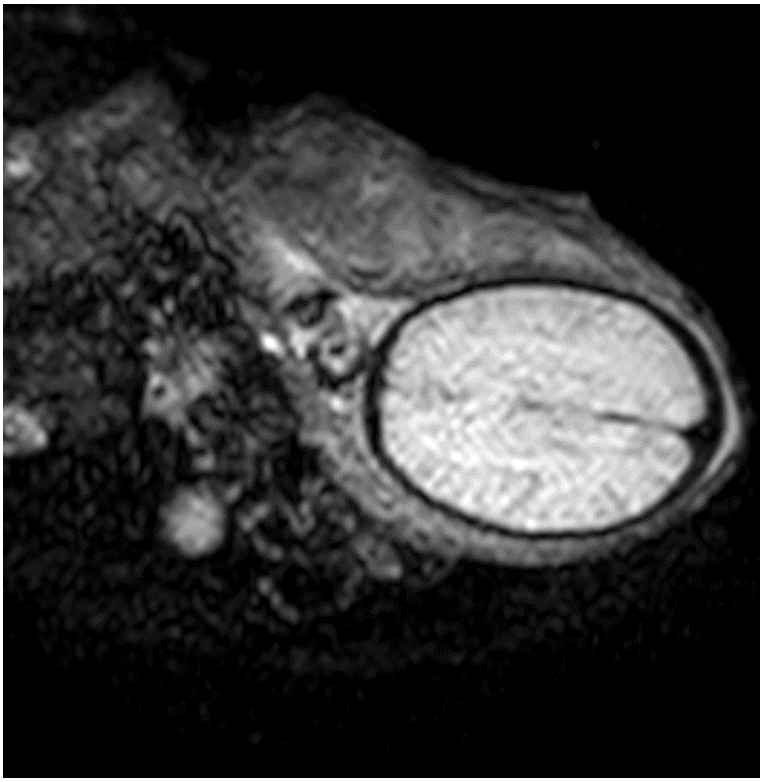


Fig. 23: The diffusion-wheigted MRI image of the fetus.

The parameters of the DICOM headers extracted with the developed tool are displayed in the following. First, the basic information about system hardware and software, image series as well as scan protocol (i.e. ExamCard) are shown in Figure 24.

```
Hardware and Software
Manufacturer's Model Name:  Ingenia
Magnetic Field Strength:  1.5
Imaging Frequency:  63.889925
Software Versions(s):  5.3.1\5.3.1.2

Series and Image
Image Type:  ORIGINAL\PRIMARY\M_SE\M\SE
Series Number:   2001
Image Acquisition Number:  20
Series Acquisition Number:  20
Series Reconstruction Number  1

ExamCard
ExamCard Name:  START FETAL FEET FIRST 14.12.2015
Body Part Examined:  ABDOMEN
Anatomic Region Code Value:  SRT.T-D4000.Abdomen
Imaged Nucleus:  1H

Sequence Type
Protocol Name:  T2/240/140_Head
Sequence Name: null
Scanning Sequence: SE
Scanning Sequence: SE
Scan Sequence:  SE
Sequence Variant: SK
Scan Options: PFP
Acquisition Type: 2D
Acquisition Type: MS
Number of Averages:  1
Series Number of Averages:  1
Scan Technique Description:  TSE
Development Mode:  NO
Scan Duration:  28.84844
Acquisition Duration:  28.848440170288086
```

```
Hardware and Software
Manufacturer's Model Name:  Ingenia
Magnetic Field Strength:  1.5
Imaging Frequency:  63.889917
Software Versions(s):  5.3.1\5.3.1.2

Series and Image
Image Type:  ORIGINAL\PRIMARY\M_SE\M\SE
Series Number:   2301
Image Acquisition Number:  23
Series Acquisition Number:  23
Series Reconstruction Number  1

ExamCard
ExamCard Name:  START FETAL FEET FIRST 14.12.2015
Body Part Examined:  ABDOMEN
Anatomic Region Code Value:  SRT.T-D4000.Abdomen
Imaged Nucleus:  1H

Sequence Type
Protocol Name:  DWI/HEAD-neu5mm
Sequence Name: null
Scanning Sequence: SE
Scanning Sequence: SE
Scan Sequence:  SE
Sequence Variant: SK
Scan Options: FS
Acquisition Type: 2D
Acquisition Type: MS
Number of Averages:  1
Series Number of Averages:  1
Scan Technique Description:  DwiSE
Development Mode:  NO
Scan Duration:  18.797026
Acquisition Duration:  18.797025680541992
```

Fig. 24: The DICOM header information in the comparison of the two image series.

The next parameters shown are characteristic for the respective weighting and are therefore listed. These are:

- for T2-weighting: Geometry, Contrast, Contrast-Encoding and
- for Diffusion-weighting: Geometry, Contrast, Contrast-Encoding and Contrast-Diffusion.

```
Geometry
Number of Geometry:  0
Percent Sampling:   65.7381591796875
Percent Phase FOV:   100
Acquisition Matrix:   0 256 168 0
Measurement Scan Resolution:  256
Number of Phase Encoding Steps:  168
Phase Enc Steps InPlane  168
Phase Enc Steps OutPlane  1
Phase Encoding Direction:   ROW
Oversampling Phase  N
Rows: 512  320
Columns: 512  320
Pixel Spacing:  0.71875\0.71875
Samples per Pixel:   1
Nr Of Slices  19
Slice Thickness:  4
Spacing Between Slices:  4.4
Number Of Slabs  0
Spatial Presaturation  N
Image Plane Orientation:  CORONAL
Patient Position:  FFS
```

```
Contrast
Spoiled:  N
Steady State:  N
Time Reversed Steady State:  N
Repetition Time:  14424.2197265625
Echo Time:   140
Echo Time Display:  140
Private Inversion Time:  0
Echo Numbers(s):  1
Nr of Echoes  1
Image Flip Angle:  90
Series Flip Angle:  90
Water Fat Shift:  0.47157538
Pixel Bandwidth:   461
Tone:  N
Flow Compensation:  N
Diffusion  N
Interactive  N

Contrast-Encoding
MR Segmented KSpace:  Y
Echo Train Length:  183
Echo Train Length:  183
RF Echo Train Length:  183
Gradient Echo Train Length:  0
TFE Factor:  0
MR Series EPI Factor:  1
Partial Fourier Frequency:  N
Partial Fourier Phase:  Y
```

Fig. 25: The DICOM header information of the T2-weighted image series.

The subgroup “Geometry” shows information on the patient position, the number of slices per stack that were developed, the amount of samples in a profile, measued during the scan and few more parameters. For example, the parameter “Acquisition Matrix” of the T2-weighted image series (Fig. 25) displays the values 0 256 168 0, which are the dimensions of the acquired raw data before reconstruction (i.e. frequency-encoding steps 256 and phase-encoding steps 168). The subgroup “Contrast” provides, for instance, information about the echo time in miliseconds and whether diffusion is used. In the case of the T2-weighted series the value is “N” denoting “no”. Another subgroup which is shown is “Contrast-Encoding. For the series of diffusion-weighted images (Fig. 26) an additional group, the “Contrast-Diffusion” is displayed. There one can find, for instance, the parameter “MR Image Diffusion Direction” with the value “I” denoting an isotropic diffusion condition for the selected image frame.

```
Geometry
Number of Geometry:  0
Percent Sampling:   85.9375
Percent Phase FOV:   100
Acquisition Matrix:   128 0 0 110
Measurement Scan Resolution:  128
Number of Phase Encoding Steps:  110
Frequency Enc Steps null
Phase Enc Steps InPlane  110
Phase Enc Steps OutPlane  1
Phase Encoding Direction:   COL
Oversampling Phase  N
Rows: 512  288
Columns: 512  288
Pixel Spacing:  0.86805558204650\0.86805558204650
Samples per Pixel:   1
Nr Of Slices  16
Slice Thickness:  5
Spacing Between Slices:  5.5
Number Of Slabs  0
Spatial Presaturation  N
Image Plane Orientation:  TRANSVERSAL
Patient Position:  FFS

Contrast-Diffusion
MR Image Diffusion Direction:  I
MR Image Enhanced:  N
MR Series Nr Of Diff BValues:  2
Diffusion BValue:  700.0
MR Image Diffusion BFactor:  700.0
MR Series Nr Of Diff Grad Orients:  4
MR Series Diffusion Echo Time:  0.0

Contrast
Spoiled:  N
Steady State:  N
Time Reversed Steady State:  N
Repetition Time:  2088.55834960937
Echo Time:   90
Echo Time Display:  90
Private Inversion Time:  0
Echo Numbers(s):  1
Nr of Echoes  1
Image Flip Angle:  90
Series Flip Angle:  90
Water Fat Shift:  7.948377
Pixel Bandwidth:   1868
Tone:  N
Flow Compensation:  N
Diffusion  Y
Interactive  N

Contrast-Encoding
MR Segmented KSpace:  Y
Echo Train Length:  55
Echo Train Length:  55
RF Echo Train Length:  1
Gradient Echo Train Length:  55
TFE Factor:  0
MR Series EPI Factor:  55
Partial Fourier Frequency:  N
Partial Fourier Phase:  Y
```

Fig. 26: The DICOM header information of the diffusion-weighted image series.

# 5. Discussion

In this chapter the presented results are discussed. It is shown what the program can help to achieve and the limitations are outlined.

| Unmet needs | Improvements by using the program |
|---|---|
| Data is saved randomly in one big folder | Data is stored separately depending the image series in subfolders<br><br>Data can be easily accessed by other software<br><br>Standardized environment is established in the MR data archive |
| Folder names do not reflect imaging information | Subfolders contain the name of the corresponding image series |
| New subfolder are created once image number succeeds 2048 | Subfolders are also taken into account and are processed |
| File names are not associated with image series or data structure | DICOM files are renamed in the new folder reflecting information of series, slice, dynamic and image number |
| No direct access to parameters from DICOM headers | Important DICOM parameters are saved in a separate text file |
| Parameters are just listed tag by tag | Parameters are sorted in subgroups and can be easily accessed |

Table 1: The comparison of the DICOM data before and after application of the developed program.

The objective was the development of a tool for the DICOM file arrangement towards structured and standardized MRI data archive. The presented table shows the corresponding improvements after applying the created DICOM tool. Two example are used to demonstrate that the points listed in the table are met. The created text files with the corresponding DICOM information facilitate the comparison and the further work with the data. There are still limitations of the created DICOM tool. It is still necessary to use external software to display the DICOM images. It would be more practical to place these directly in the folder and save them in a separate folder. In future work, one could extend the tool by this function to avoid the use of other software as far as possible. Another advantage would be the integration to the MRI scanner, which would bring further enhance in the online to offline operation efficiency.

# 6. Conclusion

In the context of this work a tool for the DICOM file arrangement is developed. DICOM is a standard for the storage and exchange of information in medical image data management. Magnetic resonance imaging is only one example of imaging technology that implements the DICOM standard. However, there is a large limitation for the immediate use of exported files. To solve this problem a tool is developed using the programming language Java with the development environment Eclipse JDT. The program essentially contains two function groups. The first function is the DICOM header extraction. The used parameters like the scan series number and the sequence name are extracted from which the folder name is created. Further parameters are dragged, sorted into subgroups and stored in a text file. The second function group deals with data restructuring. According to the extracted DICOM header information subfolders of the corresponding image series are created and the corresponding files are stored in them in a next step. The files get a new name consisting of the original name, series number, image plane number, MR series number of dynamic scans and instance number. It can be seen in the results chapter that the folder structure is improved after using the tool. There are as many subfolders as there are image series. It is also noticeable that the same number of text files with the respective grouped parameters are created. Other programs can make DICOM files visible and display the DICOM headers as well, but processing the data with these programs is more limited. ImageJ is one of these programs and plugins are also used in this work to develop the tool. Another program is the DICOM Viewer, with which the DICOM files are even arranged directly in subgroups but cannot be used directly for further processing. In the last section of the result chapter, two examples of a fetal brain examination of an MRT investigation are shown. The T2-weighted image series is compared with the diffusion-weighted image series. Apart from the differences in the images, the parameters stored in the text files also have different values. For example, the acquisition matrix or the echo time differ. Altogether, one can say that the strengths of the developed tool are the following. The folder structure is improved after the application, since the data is sorted into subfolders and can therefore be accessed more easily by other programs. The same applies to the parameters from the DICOM headers, which are stored in a separate file sorted into subgroups. The application ensures a standardized environment in the MRI data archive. On the other hand, there are also limitations. For example, further programs like ImageJ have to be used to make the image sets visible. In a further step in future work, one could solve this problem by code extension and create further subfolders with the corresponding image files. In addition, the tool could be integrated to the scanner via pride IO for the enhancement of the online to offline operation efficiency and help to bridge the gap to database exported in hospital practice. This achieves the goal of eliminating the large limitation for the immediate use of the exported DICOM files in a clinical environment.

# Bibliography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# Annex

The Java code of the program:

```
import javax.swing.*;
import java.io.*;
import  j.*;
import  j.plugin.*;
import  j.util.*;
import java.io.IOException;
import java.nio.file.CopyOption;
import java.nio.file.Files;
import java.nio.file.Path;
import java.nio.file.Paths;
import java.nio.file.StandardCopyOption;

class ArrangeData{
        public static void folderList(File folder1, String path)
        {
                if(folder1.isDirectory()){
                File[]sabfolder=folder1.listFiles();
                        String path2 = folder1.getPath();
                        if(sabfolder.length>0)
                                {
                                for(int i=0;i<sabfolder.length;i++)folderList(sabfolder[i],path);
                                }
                }
                else rename(folder1, path);
        }
        public static void rename(File file1, String path){
                String name = file1.getName();
                if(name.charAt(0)=='X' || name.charAt(0)=='P')
                        {
                        return;
                        }
                DicomTools DT = new DicomTools();

                String path1=file1.getPath();
                ImagePlus IP= new ImagePlus(path1);
                System.out.println(path1);
                String Series_Description = DT.getTag(IP,"0018,1030");
                String Series_Number = DT.getTag(IP,"0020,0011");
                String Image_Plane_Number = DT.getTag(IP,"2001,100A");
                String MR_Series_Nr_of_Dynamic_Scans = DT.getTag(IP,"2001,1081");

                Series_Number = Series_Number.replaceAll(" ","");
                int int_Series_Number = Integer.parseInt(Series_Number);
                Series_Number = String.format("%04d", int_Series_Number);

                Path FROM1 = Paths.get(path1);
          Path TO1 = Paths.get(path1+"-");
                CopyOption[] options1 = new CopyOption[]{
                           StandardCopyOption.COPY_ATTRIBUTES
                          };
                          try {
                                        Files.copy(FROM1, TO1, options1);
                                } catch (IOException e) {
                                        // TODO Auto-generated catch block
                                        e.printStackTrace();
                                }
                File file2 = new File(path1+"-");

                if(Series_Description!=null)
                {
                        Series_Description = Series_Description.replaceAll(" ","_");
                        Series_Description = Series_Description.replaceAll("/","_");
                        Series_Description = Series_Description.replaceAll("-","");
                        String NrAndDes = Series_Number + Series_Description;
                        File new_folder = new File(path+"\\"+NrAndDes);
                        if(!new_folder.exists())new_folder.mkdir();
                        File new_file = new File(new_folder.getPath()+"\\"+name);

                        file1.renameTo(new_file);
                        ImagePlus IP2= new ImagePlus(new_file.getPath());
```

```
String number =DT.getTag(IP,"0020,0013");

File new_file2 = new File(new_folder.getPath()+"\\"+name+"_"+Series_Number+"_"+Image_Plane_Number+"_"+MR_Series_Nr_of_Dynamic_Scans+"_"+Instance_Number);

if(!new_file2.exists())
    {
    new_file.renameTo(new_file2);
    }


File a = new File(NrAndDes+"_Parameter.txt");
String p1 = "Manufacturer's Model Name: "+EquipmentManufacturerModelName+"\r\n";
String p2 = "Magnetic Field Strength: "+MRImageMagneticFieldStrength+"\r\n";
String p3 = "Imaging Frequency: "+MRImageImagingFrequency+"\r\n";
String p4 = "Software Versions(s): "+EquipmentSoftwareVersions+"\r\n";

String p5 = "Image Type: "+ImageType+"\r\n";
String p6 = "Series Number:  "+SeriesNumber+"\r\n";
String p7 = "Image Acquisition Number: "+ImageAcquisitionNumber+"\r\n";
String p8 = "Series Acquisition Number: "+MRSeriesAcquisitionNumber+"\r\n";
String p9 = "Series Reconstruction Number "+MRSeriesReconstructionNumber+"\r\n";

try
{
FileWriter out = new FileWriter(path+"\\"+NrAndDes+"_Parameter.txt");
out.write( "Hardware and Software\r\n" );
out.write( p1 );
out.write( p2 );
out.write( p3 );
out.write( p4 );
out.write( "\r\n" );
out.write( "\r\n" );
out.write( "Series and Image\r\n" );
out.write( p5 );
out.write( p6 );
out.write( p7 );
out.write( p8 );
out.write( p9 );


out.close();
}
catch(IOException e){
System.out.println("Do better!");
    }


Path FROM2 = Paths.get(path1+"-");
Path TO2 = Paths.get(path1);
CopyOption[] options2 = new CopyOption[]{
        StandardCopyOption.REPLACE_EXISTING,
    StandardCopyOption.COPY_ATTRIBUTES
    };
    try {
            Files.copy(FROM2, TO2, options2);
            Files.deleteIfExists(TO1);
        } catch (IOException e) {
            // TODO Auto-generated catch block
            e.printStackTrace();
        }
    }
}
public static void main(String[]args)
{
    JFileChooser chooser = new JFileChooser("D:/");
    chooser.setMultiSelectionEnabled(false);
    chooser.setFileSelectionMode(JFileChooser.DIRECTORIES_ONLY);
    int state1 = chooser.showDialog(null,"Select Folder");
    File folder = chooser.getSelectedFile();
    String path = folder.getPath();
    File[] file = new File(path).listFiles();

    String name = file[0].getName();
    if(name.charAt(0)=='X')return;
    DicomTools DT = new DicomTools();
    String path1= file[3].getPath();
    ImagePlus IP= new ImagePlus(path1);
    String Software_Version = DT.getTag(IP,"0018,1020");
```

```
            System.out.println("Software-Version: "+Software_Version);


            File a = new File("Software Release.txt");
              String s = "Software-Version: "+Software_Version;
              try
              {
              FileWriter out = new FileWriter(path+"\\Software Release.txt");
              out.write( s );
              out.close();
              }
              catch(IOException e){
              System.out.println("Do better!");
              }
                    for(int i=0;i<file.length;i++)
                    {
                    folderList(file[i], path);
                    }
    }
```

The list of the exported DICOM tags:

| DICOM Tag (Group,Element) | Parameter |
|---|---|
| | |
| 0008,1090 | Manufacturer's Model Name: |
| 0018,0087 | Magnetic Field Strength: |
| 0018,0084 | Imaging Frequency: |
| 0018,1020 | Software Versions(s): |
| | |
| 0008,0008 | Image Type: |
| 0020,0011 | Series Number: |
| 0020,0012 | Image Acquisition Number: |
| 2001,107B | Series Acquisition Number: |
| 2001,101D | Series Reconstruction Number |
| 0020,0013 | Image Number: |
| 0020,0013 | >Image Number: |
| 2001,100A | Image Plane Number |
| | |
| 2001,10C8 | ExamCard Name: |
| 0018,0015 | Body Part Examined: |
| 2005,1397 | Anatomic Region Code Value: |
| 0018,0085 | Imaged Nucleus: |
| | |
| 0018,1030 | Protocol Name: |
| 0018,0024 | Sequence Name: |
| 0018,0020 | Scanning Sequence: |
| 2005,106E | Scanning Sequence: |
| 2005,10C0 | Scan Sequence: |
| 0018,0021 | Sequence Variant: |
| 0018,0022 | Scan Options: |
| 0018,0023 | Acquisition Type: |
| 2005,106F | Acquisition Type: |
| 0018,0083 | Number of Averages: |
| 2001,1088 | Series Number of Averages: |
| 2001,1020 | Scan Technique Description: |
| 2005,1013 | Development Mode: |
| 2005,1033 | Scan Duration |
| 0018,9073 | Acquisition Duration |
| | |
| 2005,1086 | Number of Geometry: |

| | |
|---|---|
| 2005,1074 | Stack FOV AP: |
| 2005,1075 | Stack FOV FH: |
| 2005,1076 | Stack FOV RL: |
| 0018,0093 | Percent Sampling: |
| 0018,0094 | Percent Phase FOV: |
| 0018,1310 | Acquisition Matrix: |
| 2005,101D | Measurement Scan Resolution |
| 0018,0089 | Number of Phase Encoding Steps: |
| 0018,9058 | Frequency Enc Steps |
| 0018,9231 | Phase Enc Steps InPlane |
| 0018,9232 | Phase Enc Steps OutPlane |
| 0018,1312 | Phase Encoding Direction: |
| 2005,1026 | Oversampling Phase |
| 0018,9029 | Oversampling Phase |
| 0028,0010 | Rows: 512 |
| 0028,0011 | Columns: 512 |
| 0028,0030 | Pixel Spacing: |
| 0028,0002 | Samples per Pixel: |
| 2001,1018 | Nr Of Slices |
| 2001,102D | Number Of Slices |
| 0018,0050 | Slice Thickness: |
| 0018,0088 | Spacing Between Slices: |
| 2005,1023 | Number Of Slabs |
| 2005,102F | Spatial Presaturation |
| 2001,100B | Image Plane Orientation: |
| 0018,5100 | Patient Position: |
| | |
| 2001,1060 | Nr Of Stacks |
| 2001,1036 | Stack Type |
| 2005,107B | Stack Preparation Direction |
| 2001,1032 | Stack Radial Angle |
| 2001,1033 | Stack Radial Axis |
| 2005,107E | Stack Slice Distance |
| 2005,1081 | Stack View Axis |
| 2005,1567 | Stack Reverse |
| | |
| 0018,9077 | Parallel Acquisition |
| 0018,9078 | Parallel Acq Technique |
| 0018,9069 | Parallel Reduction Factor InPlane |
| 0018,9155 | Parallel Reduction Factor OutPlane |
| 0018,9168 | Parallel Reduction Factor 2nd InPlane |
| 2005,10A1 | Syncra Scan Type |
| 2005,10A2 | COCA |

| | |
|---|---|
| 0008,9209 | Acquisition Contrast |
| 0018,9005 | Pulse Sequence Name |
| 0018,9008 | Echo Pulse Sq |

| | |
|---|---|
| 0018,9011 | Multiple Spin Echo |
| 0018,9012 | MultiPlanar Excitation |
| 0018,9018 | Echo Planar Pulse Sequence |
| 0018,9016 | Spoiling |
| 2005,1038 | Spoiled |
| 2005,1039 | Steady State |
| 2005,103B | Time Reversed Steady State |
| 0018,9017 | Steady State Pulse Sequence |
| 0018,0080 | Repetition Time: |
| 0018,0081 | Echo Time: |
| 2001,1025 | Echo Time Display |
| 0018,0082 | Inversion Time: |
| 2005,10A8 | Private Inversion Time |
| 0018,0086 | Echo Numbers(s): |
| 2001,1014 | Nr of Echoes |
| 0018,1314 | Image Flip Angle: |
| 2001,1023 | Series Flip Angle: |
| 2001,1022 | Water Fat Shift |
| 0018,0095 | Pixel Bandwidth: |
| 2005,103C | Tone: |
| 2005,1016 | Flow Compensation |
| 0018,9183 | FlowCompensationDirection |
| 2005,1014 | Diffusion |
| 2001,1024 | Interactive |
| | |
| 2005,1061 | Prepulse Type |
| 2001,101C | Prepulse Type |
| 2001,1009 | Prepulse Delay |
| 2001,101B | Prepulse Delay |
| 0018,9009 | Inversion Recovery |
| 0018,9020 | MagnetizationTransfer |
| 0018,9021 | T2Preparation |
| 0018,9022 | BloodSignalNulling |
| 0018,9024 | SaturationRecovery |
| 0018,9025 | SpectrallySelectedSuppression |
| 0018,9026 | SpectrallySelectedExc |
| 0018,9027 | SpatialPreSaturation |
| 2005,1015 | Fat Saturation |
| 2005,141A | Fat Saturation Technique |
| 2005,101B | MagnetiPrepared |
| 2005,101C | Magnet Transfer Const |
| 2005,1571 | Number of Inversion Delays |
| | |
| 0018,9014 | PhaseContrast |
| 0018,9091 | VelocityEncodingMinimumValue |
| 0018,9015 | TimeOfFlightContrast |
| 2005,1063 | MRfMRIStatusIndication |
| 0018,9019 | TagAngleFirstAxis |
| 0018,9028 | Tagging |

| | |
|---|---|
| 0018,9030 | TagSpacingFirstDimension |
| 0018,9035 | TagThickness |
| | |
| 0018,9032 | GeometryOfkSpaceTraversal |
| 2005,1034 | MRSegmentedKSpace |
| 0018,9033 | SegmentedkSpaceTraversal |
| 0018,9034 | RectilinearPhaseEncodeReordering |
| 0018,9093 | NumberOfkSpaceTrajectories |
| 0018,9094 | CoverageOfkSpace |
| 0018,0091 | Echo Train Length: |
| 2001,1082 | Echo Train Length |
| 0018,9240 | RFEchoTrainLength |
| 0018,9241 | GradientEchoTrainLength |
| 2005,1444 | TFEFactor |
| 2001,1013 | MRSeriesEPIFactor |
| 0018,9081 | Partial Fourier |
| 0018,9036 | Partial Fourier Direction |
| 2005,1028 | Partial Fourier Frequency |
| 2005,1029 | Partial Fourier Phase |
| | |
| 0018,9075 | DiffusionDirectionality |
| 2001,1004 | MRImageDiffusionDirection |
| 2001,1006 | MRImageEnhanced |
| 2005,1414 | MRSeriesNrOfDiffBValues |
| 0018,9087 | DiffusionBValue |
| 2001,1003 | MRImageDiffusionBFactor |
| 2005,1415 | MRSeriesNrOfDiffGradOrients |
| 2001,1011 | MRSeriesDiffusionEchoTime |
| 2005,10B0 | MRImageDiffusionRL |
| 2005,10B1 | MRImageDiffusionAP |
| 2005,10B2 | MRImageDiffusionFH |
| | |
| 2005,1553 | MREFrequency |
| 2005,1554 | MREAmplitude |
| 2005,1555 | MREMEGFrequency |
| 2005,1556 | MREMEGPairs |
| 2005,1557 | MREMEGDirection |
| 2005,1558 | MREMEGAmplitude |
| 2005,1559 | MRENumberOfPhaseDelays |
| 2005,1560 | MRENumberOfMotionCycles |
| 2005,1562 | MREInversionAlgorithmVersion |

| | |
|---|---|
| 2001,1008 | MRImagePhaseNumber |
| 2005,1036 | MRSeriesIsCardiac |
| 2001,1010 | MRSeriesCardiacSync |
| 0018,9037 | CardiacSynchronizationTechnique |
| 2005,1012 | MRCardiacGating |

| | |
|---|---|
| 2005,102E | MRPPGPPUGating |
| 2001,100F | MRSeriesCardiacGateWidth |
| 2001,100E | MRSeriesCardiacCycled |
| 2001,1017 | ---: 1 |
| 0018,9085 | CardiacSignalSource |
| 0018,1060 | MRImageTriggerTime |
| 2001,1007 | MRImageTypeEDES |
| 2001,100C | MRSeriesArrhythmiaRejection |
| 0018,9169 | CardiacBeatRejectionTechnique |
| 0018,1081 | Low R-R Value: |
| 0018,1082 | High R-R Value: |
| 0018,1083 | Intervals Acquired: |
| 0018,1084 | Intervals Rejected: |
| 0018,1088 | Heart Rate: |
| 2001,101F | MRSeriesRespirationSync |
| 0018,9170 | RespMotionCompTechnique |
| 2005,1031 | MRRespiratoryGating |
| 0018,9171 | RespiratorySignalSource |
| 0018,9172 | BulkMotionCompensationTechnique |
| 0020,9254 | RespiratoryIntervalTime |
| 0020,9255 | RespiratoryTriggerDelayTime |

| | |
|---|---|
| 2001,1012 | MRSeriesDynamicSeries |
| 2001,1016 | MRSeriesNrOfPhaseContrastDirctns |
| 2001,1081 | MRSeriesNrOfDynamicScans |
| 0020,0105 | MRImageNumberOfTemporalPositions |
| 0020,0100 | MRImageTempPositionIdentifier |

| | |
|---|---|
| 2005,1011 | Image Type |
| 2005,1342 | Signal Type |
| 2005,1396 | Flow Images Present |
| 2005,1398 | MobiviewEnabled |
| 2005,1399 | MRIViewBoldEnabled |
| 2005,1400 | MRVolumeViewEnabled |
| 0008,9206 | VolumetricProperties |
| 0008,9207 | VolumeBasedCalculationTechnique |
| 0008,9208 | ComplexImageComponent |
| 0018,9064 | kSpaceFiltering |
| 0018,9080 | MetaboliteMapDescription |
| 2005,1445 | AttenuationCorrection |
| 2005,144D | IsB0Series |
| 2005,144E | IsB1Series |
| 2005,10A9 | MRSeriesGeometryCorrection |
| 2005,1017 | Fourier Interpolation |
| 0018,1100 | Reconstruction Diameter |

I

| | |
|---|---|
| 0028,1052 | Rescale Intercept: |
| 0028,1053 | Rescale Slope: |
| 0028,1054 | Rescale Type: |
| 2005,100D | Scale Intercept: |
| 2005,100E | Scale Slope: |
| 2005,140A | Rescale Slope Original: |
| 2005,140B | Rescale Type Original: |
| 2005,100F | Window Center Original: |
| 2005,1010 | Window Width Original: |
| 0028,2110 | Lossy Image Compression: |

| | |
|---|---|
| 2005,1037 | MRSeriesIsSpectro |
| 2005,1325 | MRSpectroSIB0Correction |
| 2005,1331 | MRNumberOfSpectraAcquired |
| 0028,9001 | DataPointRows |
| 0028,9002 | DataPointColumns |
| 2001,1001 | Chemical Shift |
| 2005,1446 | FWHMShim |
| 0018,9101 | FrequencyCorrection |
| 0018,9199 | Water Referenced Phase Correction |

| | |
|---|---|
| 0018,1316 | SAR: |
| 0018,1318 | dB/dt: |
| 0018,1320 | B1rms |
| 0018,9174 | ApplicableSafetyStandardAgency |
| 0018,9177 | OperatingModeType |
| 0018,9178 | OperatingMode |
| 0018,9179 | SpecificAbsorpRateDef |
| 0018,9180 | GradientOutputType |
| 0018,9181 | SpecificAbsorpRateValue |
| 0018,9182 | GradientOutput |
| 2005,142E | MRSeriesDBdt |
| 2005,142F | MRSeriesProtonSAR |
| 2005,1442 | AIMDB1RMSLimit |
| 2005,1492 | SEDvalue |

| | |
|---|---|
| 0020,0032 | Image Position (Patient): |
| 0020,0037 | Image Orientation (Patient): |
| 0020,0052 | Frame of Reference UID: |
| 0020,0060 | Laterality: |
| 0020,1040 | Frame of Ref Position Indicator: |
| 0020,1041 | Image Plane Location |

| | |
|---|---|
| **0020,9072** | **Frame Laterality** |
| **2001,1015** | **MRSeriesNrOfLocations** |
| **2005,1563** | **SagittalSliceOrder** |
| **2005,1564** | **CoronalSliceOrder** |
| **2005,1565** | **TransversalSliceOrder** |
| **2005,1566** | **SeriesOrientation** |
| **2005,1000** | **MRImageAngulationAP** |
| **2005,1001** | **MRImageAngulationFH** |
| **2005,1002** | **MRImageAngulationRL** |
| **2005,1008** | **MRImageOffCentreAP** |
| **2005,1009** | **MRImageOffCentreFH** |
| **2005,100A** | MRImageOffCentreRL |
| **2005,1071** | **MRStackAngulationAP** |
| **2005,1072** | **MRStackAngulationFH** |
| **2005,1073** | **MRStackAngulationRL** |
| **2005,1078** | **MRStackOffcentreAP** |
| **2005,1079** | **MRStackOffcentreFH** |
| **2005,107A** | **MRStackOffcentreRL** |
| **2005,143C** | **MRStackTablePosLong** |
| **2005,143D** | **MRStackTablePosLat** |
| **2005,143E** | **MRStackPosteriorCoilPos** |

| | |
|---|---|
| **2005,143B** | **Coil Survey** |
| **0018,1250** | **Receiving Coil:** |
| **0018,1251** | **Transmitting Coil:** |
| **0018,9043** | **Receive Coil Type** |
| **0018,9044** | **Quadrature Receive Coil** |
| **0018,9047** | **MultiCoil Element Name** |
| **0018,9048** | **MultiCoil Element Used** |
| **0018,9051** | **Transmit Coil Type** |
| **0018,9059** | **DeCoupling** |

| | |
|---|---|
| **0008,1030** | **Study Description:** |
| **0020,0010** | **Study ID:** |
| | |
| **0040,0254** | **Performed Procedure Step Description:** |
| **0032,1060** | **Requested Procedure Description:** |
| **0040,1001** | **Requested Procedure ID:** |
| | |
| **0008,0020** | **Study Date** |
| **0008,0021** | **Series Date** |
| **0008,0022** | **Image Acquisition Date** |
| **0008,0030** | **Study Time** |
| **0008,0031** | **Series Time** |
| **0008,0032** | **Image Acquisition Time** |

| | |
|---|---|
| 0010,0010 | Patient's Name: |
| 0010,0020 | Patient ID: |
| 0010,0030 | Patient's Birth Date: |
| 0010,0040 | Patient's Sex: |
| 0010,1010 | Patient's Age: |
| 0010,1030 | Patient's Weight: |