COT5930 Digital Image Processing - Spring 2021
Assignment 2 - Exploring MATLAB apps and toolboxes for image processing
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Exploring DICOM support in MATLAB

This report explores MATLAB's DICOM browser and the DICOM functions that are part of the image processing toolbox.

The DICOM standard

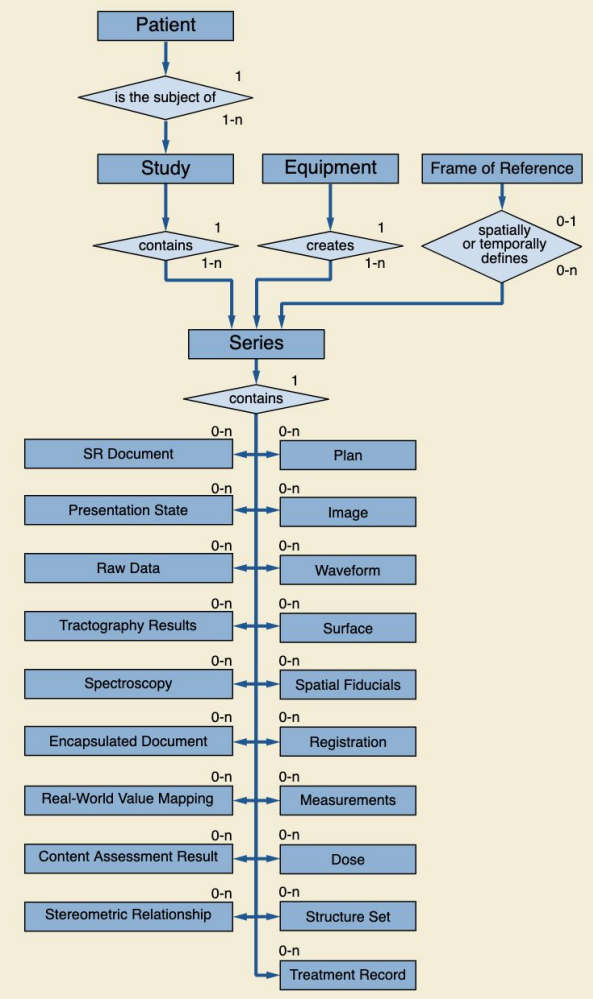
DICOM (Digital Imaging and Communications in Medicine) is the "international standard for medical images and related information. It defines the formats for medical images that can be exchanged with the data and quality necessary for clinical use." (from the DICOM standard website).

DICOM is not only about medical images. It is a collection of services to store and exchange medical data across different types of equipment and networks.

Storing data in a file is a specific part of DICOM, documented in part 10 (PS3.10). Each file is a *study* (a logically related series of images and other documents from one patient), containing one or more *series* (a set of images of the same modality, i.e. acquired with one piece of equipment, at a specific time). Each series has one or more images (frames).

Besides the images, a DICOM file also stores information about the patient, the equipment used to acquire the images, how the equipment was configured, among other items. *Storing ancillary information with the images in one file is an important concept in DICOM*. Together, the images and associated information form a data set.

The figure on the right, extracted from the DICOM entity-relationship model, shows the hierarchy of objects stored in a DICOM file.



There are two main file types in DICOM:

- DICOM: a file that contains one or more series, each with one or more images (or *frames*) and their associated description. These files usually have the extension .dcm.
- DICOMDIR: a file that describes a collection of DICOM (and possibly non-DICOM) files. This collection of files is called a *file set*. These files are usually named DICOMDIR and placed in the same directory with the .dcm files they refer to.

MATLAB DICOM browser and functions

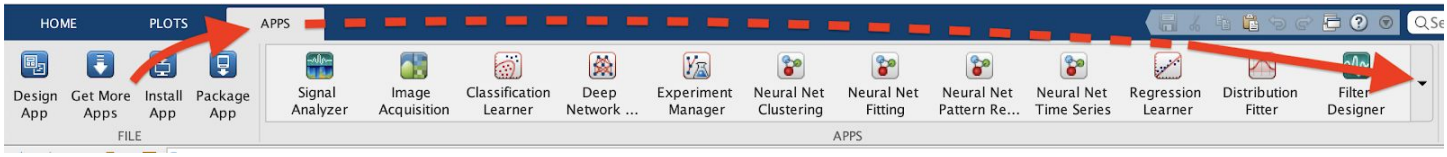
The MATLAB DICOM browser is an application to browse DICOM and DICOMDIR files. The browser uses the DICOM functions that are part of MATLAB's image processing toolbox. The MATLAB DICOM functions work with files. They do not support other DICOM functions, such as networking.

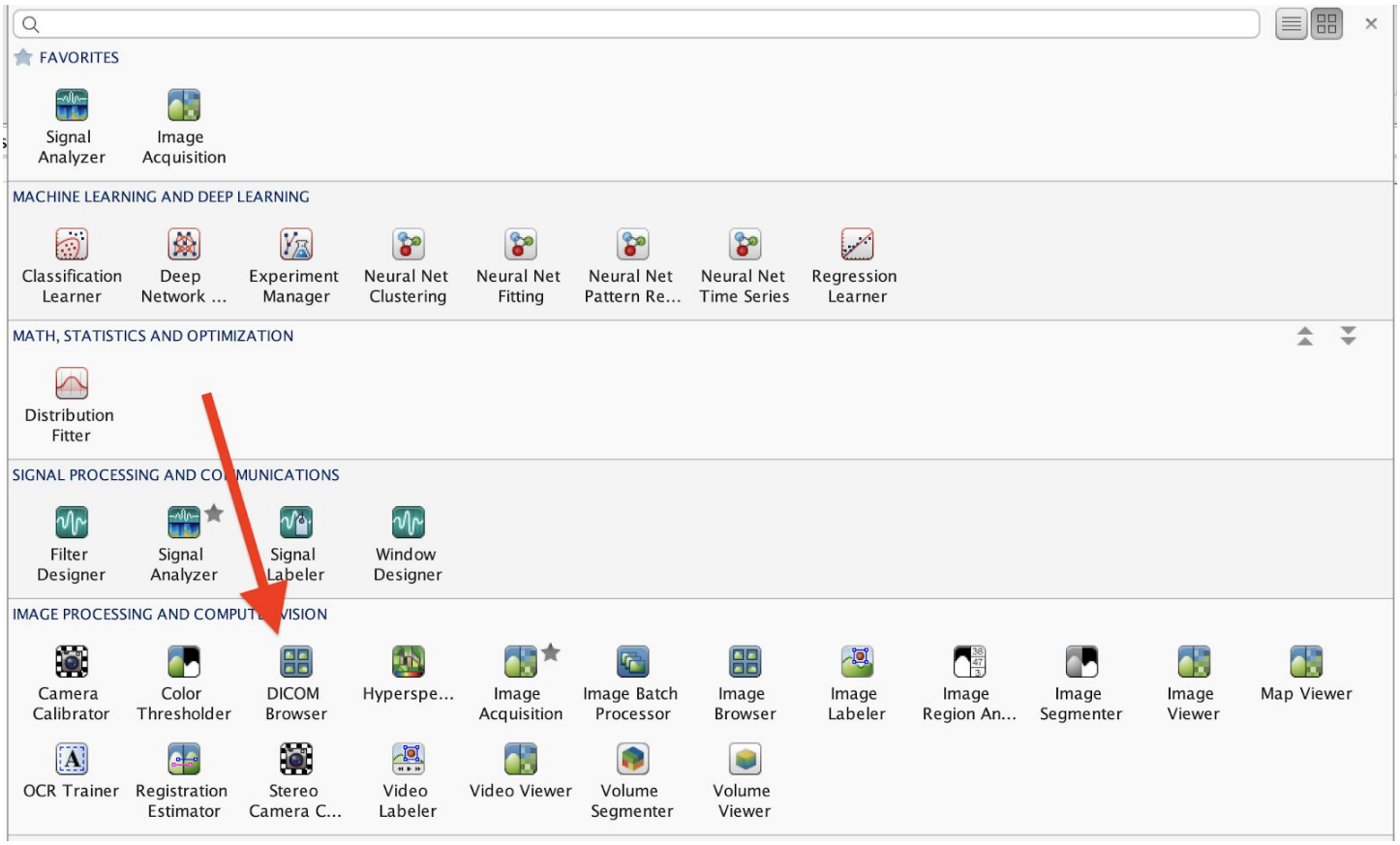
The MATLAB image toolbox (version R2020b) has these sample DICOM files:

- DICOM: CT-MONO2-16-ankle.dcm, US-PAL-8-10x-echo.dcm, knee1.dcm, knee2.dcm, and rtstruct.dcm
- DICOMDIR: a DICOMDIR file that refers to CT-MONO2-16-ankle.dcm, US-PAL-8-10x-echo.dcm, knee1.dcm, and knee2.dcm DICOM files.
    - This information was reverse-engineered with "strings DICOMDIR | grep '.dcm'"

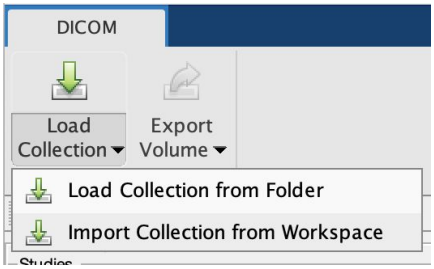
The DICOM browser

The DICOM browser is available under Apps > Image processing and computer Vision > DICOM browser.





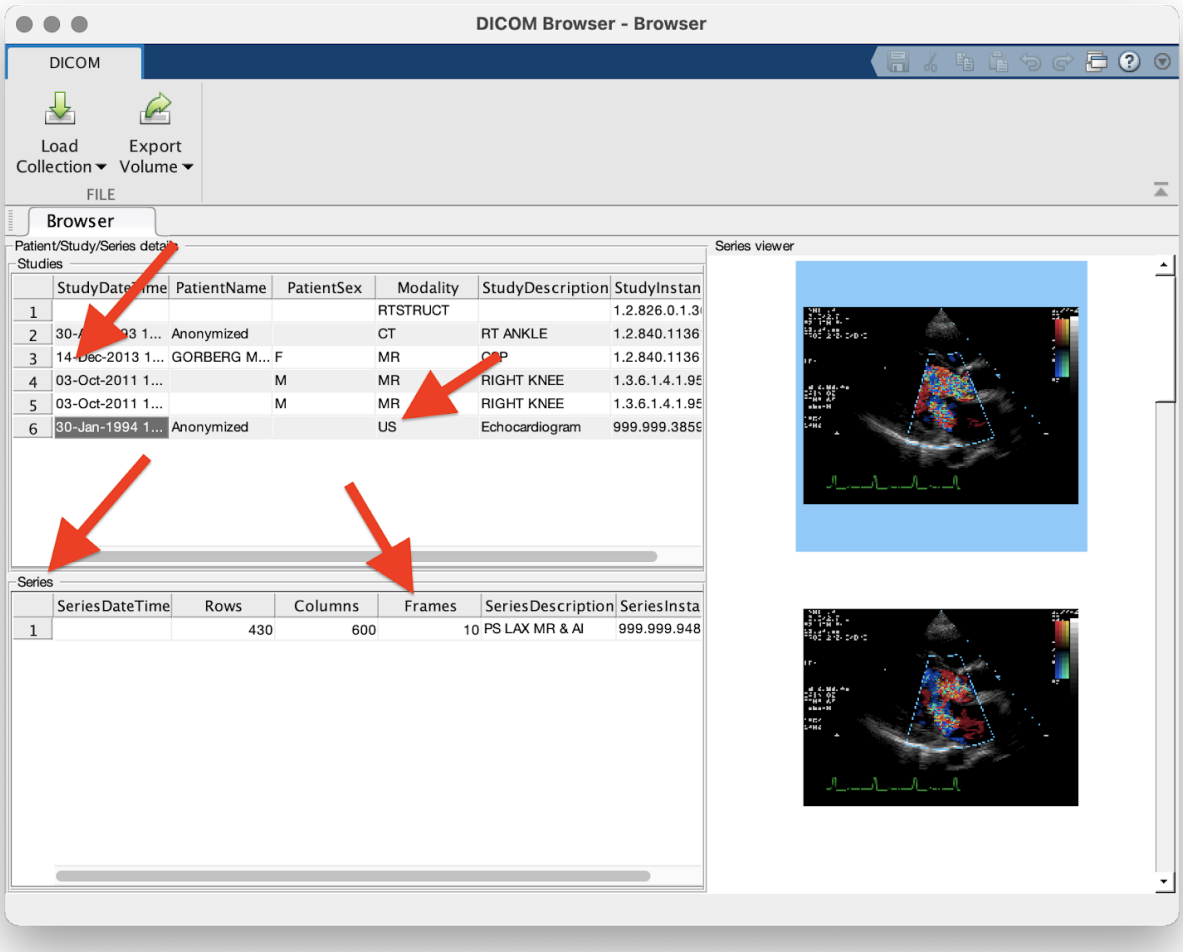
After the browser opens, click on "Load Collection" and "Load Collection from Folder" to load DICOM files from a folder.



A more convenient way is to start the browser through the command line. The command below starts the browser and points it to the image processing toolbox sample images directory. The browser looks for all files with the extension .dcm and for DICOMDIR in that directory.

```
>> dicomBrowser(fullfile(matlabroot,'toolbox/images/imdata'))
```

In the picture below, the browser found six studies (from .dcm files) in the directory and displayed them in the top panel. In this example, the user selected study number six, which contains one series with ten images (frames) from an ultrasound machine (modality "US"). Details of the series are shown on the bottom panel. The images are shown on the right panel.

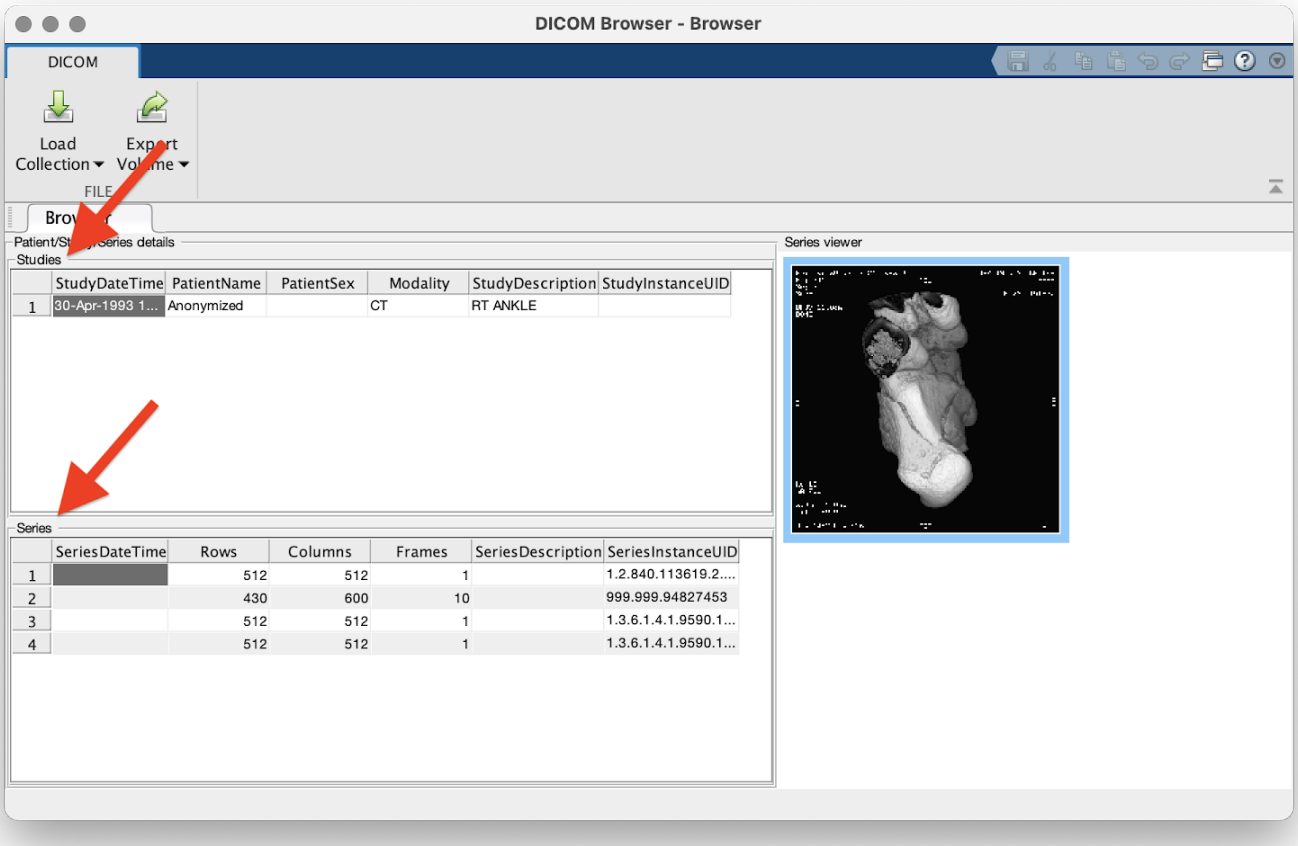


Side note: the MATLAB DICOM browser shows the modality in the "Studies" panel. It would be better to show the modality in the "Series" panel because the modality is associated with the series in DICOM.

The command below starts the browser and opens a DICOMDIR file.

```
>> dicomBrowser(fullfile(matlabroot,'toolbox/images/imdata/DICOMDIR'))
```

This file has one study, shown in the top panel. The study has four series, shown on the bottom panel.

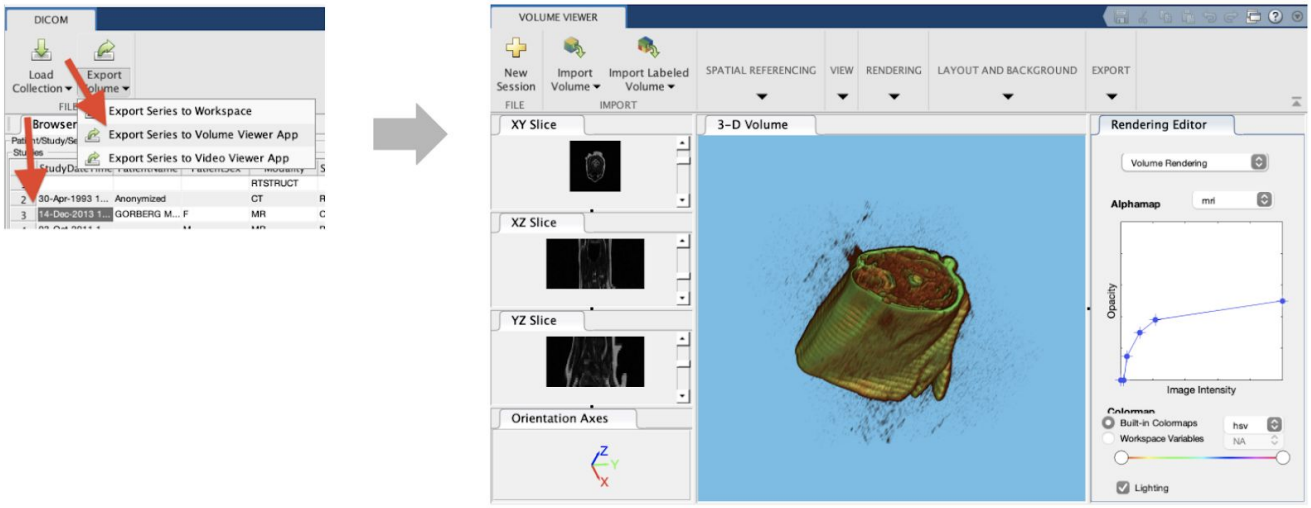


Interacting with other MATLAB tools

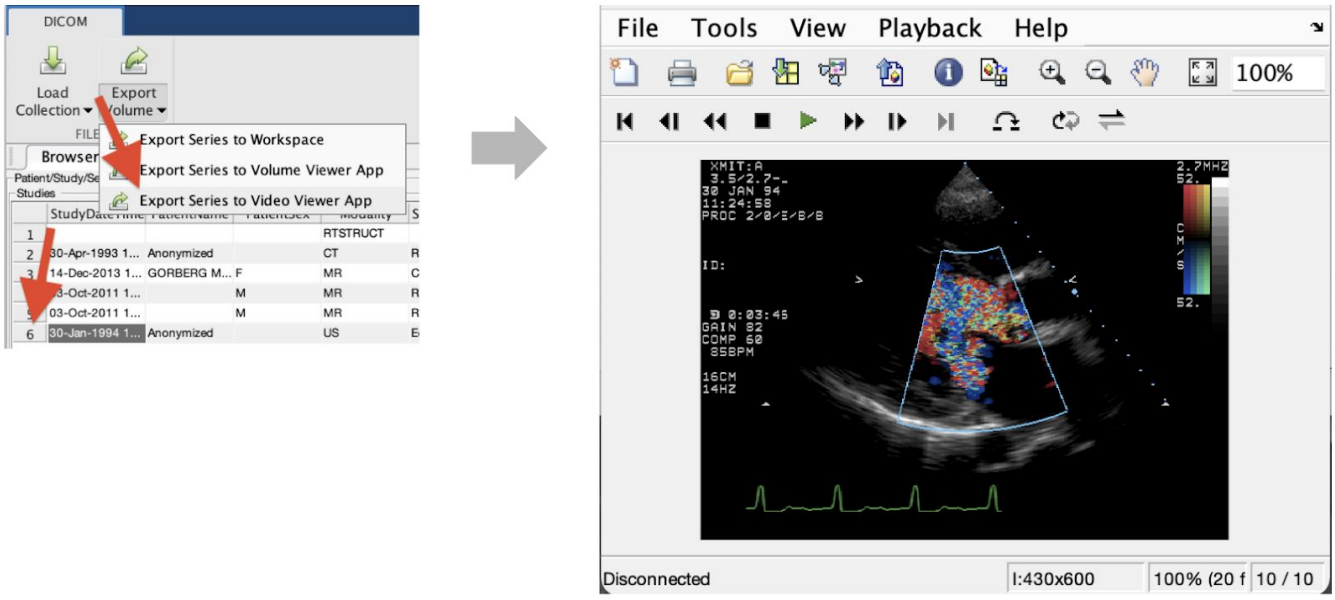
Some medical devices capture multiple images from a patient. For example, a magnetic resonance imaging (MRI) device captures multiple images to build a 3D model of a body part. An ultrasound device captures multiple frames of organs that can be animated.

Images captured with such devices result in one DICOM file that has multiple frames (images). The DICOM browser can export the frames to other MATLAB tools that know how to assemble them into their corresponding view.

For example, study three in the image processing toolbox sample images is an MRI. Exporting it to the MATLAB volume viewer app results in a 3D view of the body part.



Study six is an ultrasound series with ten frames. By exporting it to the [MATLAB video viewer app] we can play the ten frames as a short movie.



Experiment

While the DICOM browser is useful for a quick overview of studies and series, it hides the complexity of DICOM a bit too much. More specifically, it hides the complexity of interpreting DICOM images.

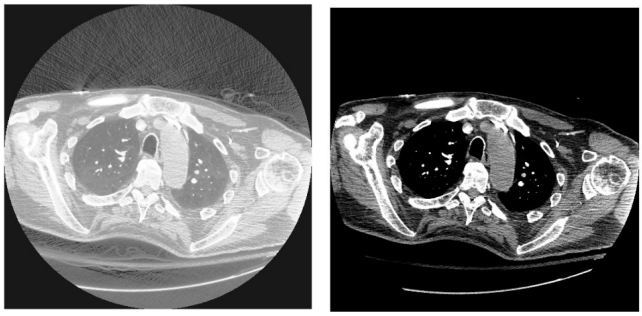
To understand how to process DICOM images, in this assignment we will experiment with:

1. Reading DICOM information to understand what values are used to interpret the image.
2. Showing DICOM images with a large grayscale, more than fits in the 256 gray levels supported by a computer screen.

Given the complexity of medical images, to keep the assignment doable in the designated time frame it will be limited to CT images.

Conclusions

- DICOM is complex…
- ...but its complexity reflects the complexity of healthcare in general and of medical image acquisition, storage, and analysis in particular.
- This was my first experience with images that have a grayscale larger than 256 levels. It is enlightening to understand why a larger scale is needed and how windowing is necessary for these images.
- Having knowledge about the dataset beats smart algorithms. For example, applying the dynamic contrast adjustment function `histeq` to the sample file 012c12fe09c3.dcm results in the image on the left. Using the window provided in the DICOM file (presumably by someone who understands what the file represents), results in the picture on the right, much better contrast for this case.



- Live script controls are limited to hard-coded values. It works for simple cases but is not scalable. For example, the first control in the live script is a list of sample files. It has been populated by hand. The script would be more resilient and maintainable if we could read the list of .dcm files from the directory and populate the control dynamically.

What I would do if I had more time

- Explore other types of medical images

Resources consulted

Articles, guides, and other sources of information consulted for this assignment.

- Managing DICOM images: Tips and tricks for the radiologist: describes how to work with DICOM files from the point of view of medical professionals. It is a good introduction to understand how they are used in practice.
- Understanding and Using DICOM, the Data Interchange Standard for Biomedical Imaging
- DICOM composite object information (entity-relationship model): how studies, series, images, and other pieces of data are related.
- Understanding DICOMs. An In Depth Hands On approach to how to… | by Amrit Virdee: although it uses Python, it is a good, practical description of how to handle DICOM files, including files with multiple images and images with a large grayscale (image windowing).
- A Matter of Grayscale: Understanding Dicom Windows | by Amrit Virdee: from the same author, explains the concept and application of windowing in detail.
- DICOM Library: "free online medical DICOM image or video file sharing service for educational and scientific purposes."

- Kaggle's CT images from cancer imaging archive with contrast and patient age
- The official DICOM terminology.
- Thyroid Segmentation in Ultrasonography Dataset | OpenCAS has multi-frame DICOM files (more than one image per file).
- A Practical Introduction to CT: a video that explains how to work with CT images, showing how windowing is used to analyze different types of issues and other artifacts in the image.
- fastai/60_medical.imaging.ipynb at master · fastai/fastai · GitHub: Jupyter notebook demonstrating how to process medical images.

From MATLAB

- Accessing data in DICOM files - MATLAB & Simulink
- DICOM Example Files - File Exchange - MATLAB Central