PYCAD
PYTHON ACADEMY

A Beginner's Guide to Medical Imaging
No code

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Writer Message

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I am doing a PhD in computer vision where I work in action and anomaly recognition and detection.

Coding has always been my passion, and I've always enjoyed writing code. In the beginning, I started with easy projects like Arduino projects, where I built the basic circuit and wrote the code to control it. Even though some people told me that Arduino is for kids, I continued working because it was a great time and I was learning a lot. Because the purpose of using Arduino is to help you become more comfortable writing code and understanding how it operates in actual circuits.

After working on several Arduino projects, I wanted to do something that would improve my skills and give me more ability to work on real-world problems. So I began learning C++, which is one of the more difficult programming languages, but it was a great experience, and after learning it, I began making YouTube videos about it, which helped me learn more so that I could make more YouTube videos.

After learning C++, I moved on to the world of computer vision, which led me to another level of programming where I learned Python (which was very simple because I already knew C++) and used it for computer vision tasks. It is now my full-time job and passion.

Mokhtari

You Will Never Find IT Easy at The First Try!

Table of Contents

Writer Message 03

A quick introduction about myself.

Introduction to the Book 04

Introduction to the ebook and what will be covered.

What is Medical Imaging 05

In this section, I will give some definitions and what are the file formats used in medical imaging.

The Challenges for a Computer Vision Engineer 10

In this section, I will discuss the challenges that a computer vision enginner can face when working with medical imaging.

The Software for Medical Imaging Treatements 11

In this section, I will discuss the free and paid software that can be used to visualize and segment medical images.

Introduction to Medical Imaging with Python 12

When it comes to how to use Python with Medical Imaging, there are some specific libraries that can be used to facilitate your life.

Machine Learning for Medical Imaging 14

Introduction to MONAI and its functionalities (tools, DL architectures...).

The Best YouTube Videos 18

Some YouTube videos that I found helpful for my projects.

The Best GitHub Repositories 19

Direct links to GitHub repositories that may help you for your Medical Imaging projects.

Other Resources 19

Links to other resources that can help you start your projects.

Contact 20

Contact information for any questions about this book

Key Points

Medical Imaging, Machine Learning, Deep Learning, Computer Vision, MONAI, Python.

Introduction

04

Medical imaging is a vast field that includes many different types of images, such as MRI, CT, PET, and X-ray images. These images are a rich source of information about the human body. Images are often used to diagnose disease and plan medical procedures.

Python is one of the most popular programming languages in use today. It has a large number of libraries for handling scientific data formats like dicom images and nifti files which are used in medical imaging.

This ebook will teach you how to read, process, analyze and visualize medical imaging data using Python with the help of real-world examples.

What is Medical Imaging?

05

Medical imaging is the process of creating images of the human body for medical purposes. It is a branch of medical science that uses sound waves and electromagnetic radiation to generate images of human anatomy, both for diagnostic and therapeutic purposes.

What are the types of medical images.

Medical images can be taken from different sources, such as x-rays, CT scans, MRIs, radio graphics and echocardiograms. All these types of medical images have their own advantages and disadvantages.

X-ray: X-rays are a type of electromagnetic wave radiation. Images of the inside of your body are created using X-ray imaging. The images depict various parts of your body in various shades of black and white. This is due to the fact that different tissues absorb different amounts of radiation. Because calcium in bones absorbs the most x-rays, bones appear white. Fat and other soft tissues absorb less and appear gray as a result. Because air absorbs the least, the lungs appear black.

CT-scans: A type of imaging is **C**omputed **T**omography (CT). It creates cross-sectional images of your body using specialized x-ray equipment. CT scans are used by doctors to look for:

- Fractures (broken bones) (broken bones)
- Cancers
- Clots in the blood
- Heart disease symptoms
- Internal bruising

You lie still on a table during a CT scan. Slowly, the table moves through the center of a large X-ray machine. The examination is painless. During some tests, you will be given a contrast dye, which will make certain parts of your body stand out more in the image.

MRIs: Magnetic **R**esonance **I**maging (MRI) examines organs and structures within your body using a large magnet and radio waves. MRI scans are used by doctors to diagnose a wide range of conditions, from torn ligaments to tumors. MRIs are extremely helpful in examining the brain and spinal cord.

You lie on a table that slides inside a tunnel-shaped machine during the scan. The scan can take a long time, and you must remain still during it. The scan is completely painless. The MRI machine is extremely loud. Earplugs may be provided by the technician.

Tell your doctor before getting a scan if you:

- Are you pregnant?
- You have metal fragments in your body. If you have a shrapnel or bullet injury, or if you are a welder, you may have metal in your body.
- Have a cardiac pacemaker or a metal artificial joint in your body?

Echocardiogram: An echocardiogram is a test that creates images of the heart using sound waves. It produces a more detailed image and information than a standard x-ray image. You will not be exposed to radiation during an echocardiogram.

The file format used in medical imaging

A lot of file formats can be used while working with medical imaging, some of them are the direct output of the machines, and others are created only for image processing purposes. I will cite some examples which are the most used file format in computer vision with medical imaging.

Dicom files (Digital Imaging and Communications in Medicine): Dicom files are a specific format used in medical imaging to store MRIs, CT scans, PET scans, and other scan formats. These files are not the same as the other types of images we use in our daily lives, such as PNG, Jpeg, JPG, TIFF, and so on. The dicom files contain a wealth of information that allows doctors to save specific patient details. Some of these details include the patient's name, age, and consultation date...

Do the dicom files contain a normal image?

Yes, the dicom files contain images known as the pixel array, which is an array containing the pixel values, and we can visualize the image by extracting this array. The image in a dicom file represents one slice of the entire scan, indicating that it is a laser cut. It could be something like this:

Figure 1: example of one slice

This is a coronal view of the patient, one of three possible views: axial, sagittal, and coronal.

Figure 2: example of axial, sagittal and coronal orientations

Is one dicom file enough to represent a patient?

One dicom file represents one cut, so to represent an entire patient, we need multiple slices, which are multiple dicoms, and we can combine them to get an entire case.

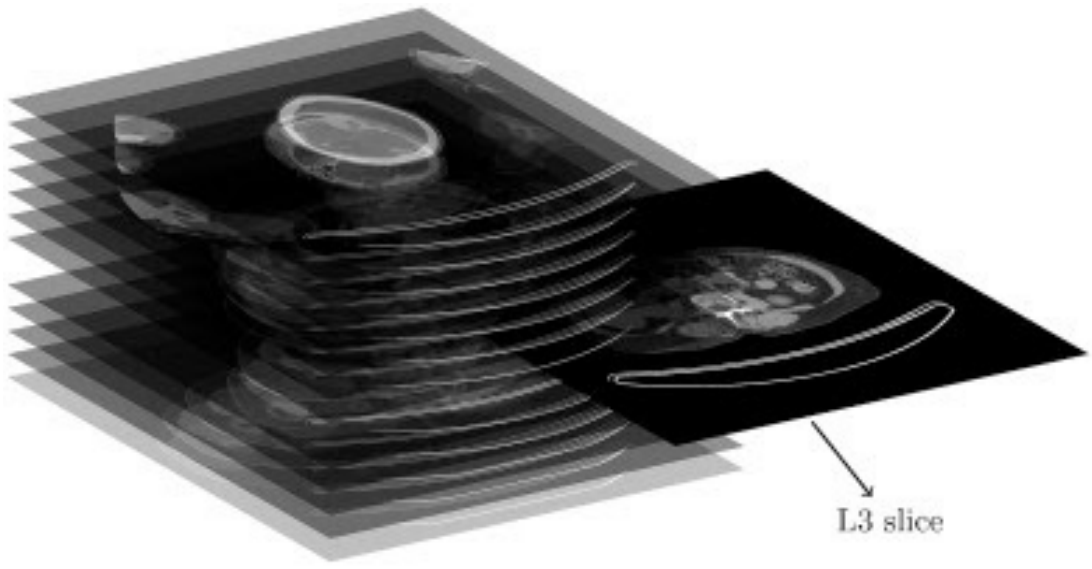

Figure 3: how the slices are super-imposed

Nifti files (**N**euroimaging **I**nformatics **T**echnology **I**nitiative): The nifti files are 3D representations of entire scans such as CT scans, CBCTs, PET scans, MRIs, and so on. It contains the same data as the DICOM file, but instead of a single slice, it contains a 3D array containing the entire case.
We can always convert multiple dicom series into a single nifti file or a single 3D nifti file into multiple dicom series.

The best resources to understand how medical imaging works

A lot of resources are available for medical imaging, either for understanding pure anatomy or for coding. In this section, I will be giving you the resources to understand the anatomy and in the next sections I will give you the resources for coding.

- Website for definitions of the different medical imaging types, **here**.
- Websites for the best medical imaging papers, **1**, **2**, **3**, **4**, **5**, **6**, **7**, **8**, **9**.
- Websites to get the best datasets for medical imaging, **1**, **2**, **3**, **4**, **5**, **6**, **7**, **8**, **9**, **10**, **11**, **12**, **13**, **14**, **15**, **16**.

The Challenges for a Computer Vision Engineer

10

Medical imaging is a very important part of the healthcare industry. It is essential for the diagnosis and treatment of diseases, injuries, and other medical conditions. With the help of medical imaging, doctors can see what is going on inside a patient's body without having to cut them open or do surgery. Computer vision engineers are required to analyze these images and provide solutions to the challenges they might face with such images.

Some of these challenges include low contrast in images, image noise or artifacts, occlusions (objects blocking other objects), motion blur (when an object moves too fast), and poor resolution. The computer vision engineer will have to find ways to overcome these challenges so that they can provide accurate diagnoses for their patients.

And one of the most difficult challenges that most engineers face is a lack of data, because medical imaging data is extremely sensitive and difficult to obtain. The second difficult challenge that computer vision engineers face is a lack of understanding of disease anatomy or pathology. The last one is data annotation, which is especially important when working with 3D images such as CT scans, CBCTs, and MRIs. Manual segmentation is extremely difficult and time consuming.

The software that can be used to process medical images

11

In this section, I will be sharing the list of the free and paid software that can be used for medical image visualization and annotation.

The free software and the operating systems available

- 3D slicer (Free)
- ITK snap (Free)
- Simpleware from Synopsys (Paid)
- Axial3D (Paid)
- D2P (Dicom to Print) (Paid)
- Virtual Surgical Planning (Paid)
- 3D LifePrints Design Models (Paid)
- 3mensio Workstation (Paid)
- ImFusion (**Free** for visualization | **Paid** for annotation and exportation)
- Materialise Mimics (Paid)

Introduction to medical imaging with Python

12

In this section, I will list the Python packages, YouTube tutorials, blog posts, and GitHub repositories that will assist you in getting started with medical imaging.

There are a few packages that can be used to process medical images, but they are more than adequate for the specific operations that you may require to begin working in medical imaging.

Reading Medical Images

As discussed, medical imaging formats such as Dicoms, Nifti, Nrrd, and so on are not normal formats of images, which means we cannot load/read them using normal Python libraries such as OpenCV, Pillow, ... etc. To read medical imaging formats, you can use:

- Pydicom: for dicom files
- Nibabel: for nifti files
- SimpleITK: for dicom and nifti files
- MedPy: for dicom, nifti and more other formats that can be found in the documentation
- VTK: for dicom, nifti and lots of other formats, you can check the documentation for information

What are the libraries that can be used to visualize medical images

- SimpleITK, Pydicom, Nibabel, MedPy + Matplotlib | Example
- VTK: it can be used to create a good 3D viewer | Example

Edit Medical Images

Editing medical images is not impossible, even if they have a unique format; we can always edit or even create them from a standard array. All of this is possible with the same libraries that we mentioned earlier (pydicom, nibabel, simpleITK,..). I'll share some of my blog posts that contain these types of edits with you (GitHub repositories are included).

- Convert Dicom files into JPG/PNG images.
- Convert JPG/PNG images into Dicom files.
- Convert a 3D numpy array into a Nifti file.
- Convert a Nifti file into Dicom series.
- Convert a Nifti file into Dicom series (Optimized).
- Convert a Nifti file into STL (for 3D printing).
- Anonymize Dicom files.

Machine Learning for Medical Imaging

14

Machine learning has been used for medical imaging for a long time. It was first introduced in the field of radiology. It is now being used in many other medical fields as well.

There are several challenges that come with machine learning in the field of medicine. One of them is that there is a need to have high-quality data to train the machine learning algorithm, which is not always available. Another challenge is that there are many different types of machine learning algorithms and choosing which one to use can be difficult and time-consuming.

Introduction to MONAI

Because of its efficiency and high accuracy, deep learning has become a superhero in the healthcare field, where it is used for all tasks. However, because the community is still in its early stages, tools for developing deep learning models for medical imaging are scarce. The most difficult aspect of medical imaging is preprocessing the data because medical data differs from standard RGB/Grayscale images. It requires special processing and functions to either preprocess or post-process them. MONAI, a large library, is one of the best and largest open source frameworks for medical imaging, and it is the subject of this blog post.

MONAI is an open-source framework developed by Kitware, a company that has many open-source tools. Specifically, MONAI was developed by: Prerna Dogra, Jorge Cardoso, Sebastien Ourselin, Kimberly Powell, Andy Feng, Nic Ma, Wenqi Li, and the over 100 (!) open-source developers.

It is built on PyTorch, with many PyTorch functions imported and modified. There are also MONAI-specific functions that can be used for pre- and post-processing medical images (Dicoms and Nifti). MONAI includes a plethora of cutting-edge architectures that you can simply import and use.

Where It Can Be Used

The pre- and post-processing of medical data is a unique application of MONAI. Because the deep learning component can be accessed through other libraries. However, special functions and tools are required to preprocess medical images. And MONAI has everything we need, from uploading data to preprocessing and even augmenting it (which is a very difficult process in medical images.)

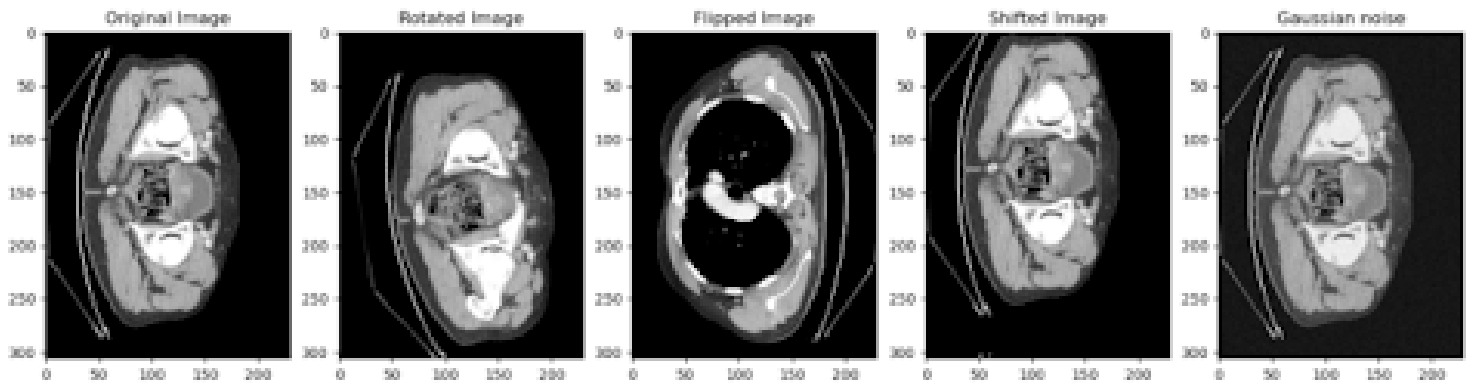

Figure 4: examples of the generated data

You can find all of the transforms you need for preprocessing, postprocessing, and data augmentation **here**.

Tasks Covered by MONAI

MONAI has 2D and 3D models and can be used for image classification and segmentation (3D convolutions are often used for the 3D medical data).

For those who are unfamiliar with the distinction between image classification and image segmentation, image classification consists of classifying the entire image into a class or another without regard to the object location in the image, whereas image segmentation consists of classifying each pixel (voxel for 3D) to a class or another, which aids in recognizing the exact location of the object in the image.

Here's an illustration of the distinction between image classification and image segmentation:

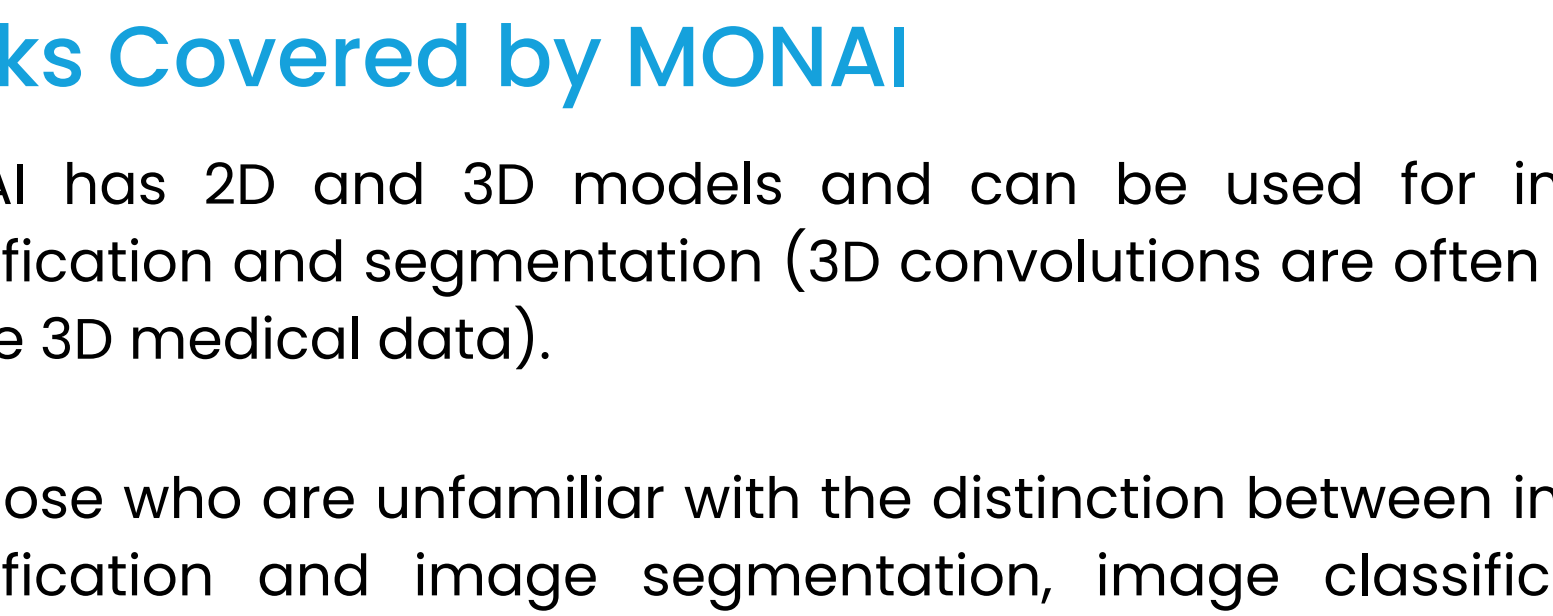

Figure 5: the difference between image classification and image segmentation

MONAI implements numerous models, including U-Net, DynNet, UNETR, and a variety of state-of-the-art architectures. You can find them all by following this link.

Why MONAI

I recommend MONAI because it is all-inclusive. It can be used for everything from gathering raw data to deploying your final model! It consists of three modules: MONAI-Core, MONAI-Labels, and MONAI-Deploy. You only need these three modules to set up a deep learning pipeline.

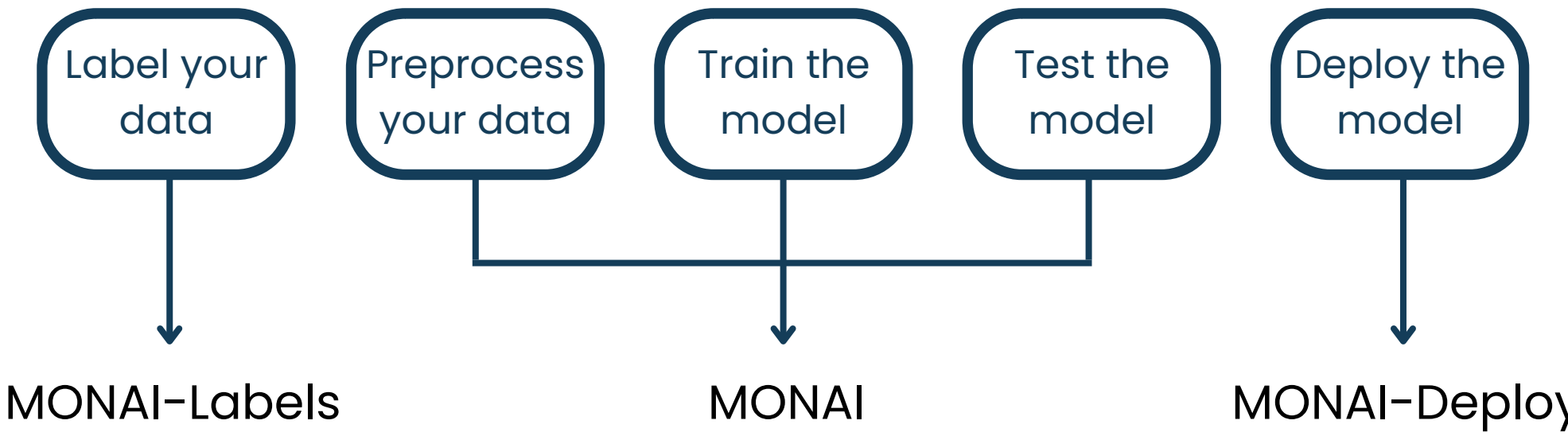

Figure 6: the tools provided by MONAI team

Resources

18

After I gave you a quick overview of MONAI, I'd like to share some resources that I created and believe will help you get started on your projects. Before that, you can look at the MONAI-GitHub Project's repository for some examples to help you understand the fundamentals of MONAI.

My Course

My free 5 hours course about 3D automatic liver segmentation using MONAI and PyTorch can be found here.

Best YouTube Videos

In this section, I will site the best YouTube videos about deep learning for medical imaging.

- Nuclei segmentation using U-Net.
- Lungs segmentation using Scipy and Skimage.
- 3D tooth segmentation from MRIs using U-Net.
- Training medical image segmentation using less labeled data.
- Denoising MRI images.
- Brain Tumor detection based on MRI Image Segmentation using U-Net.

- Brain Tumor Detection Using CNN with Python Tensorflow Sklearn OpenCV.
- Breast Tumor Segmentation and Classification using Ultrasound images.

Best GitHub Repositories

- Awesome GAN for Medical Imaging.
- Awesome Transformers in Medical Imaging.
- Bi-Directional ConvLSTM U-Net with Densely Connected Convolutions.
- A 3D multi-modal medical image segmentation library in PyTorch.
- Pytorch-dicom-classification.
- MedMNIST.
- Google Cloud AutoML Vision for Medical Image Classification.
- NIH ChestXray14 image classification.

Other Resources

- Get a summary of top publications and breakthroughs in Machine Learning.
- Computer Vision and Machine Learning e-Mailing List.

Thanks for your Attention.

Please let me know if you require any additional information about this ebook!

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