قســـم الانظمة الطبية الذكية
المرحلة الثالثة

Subject : Medical image processing

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Class 4: Medical image file format

IMAGE FILE FORMAT

- Medical image file formats are primarily categorized based on their purpose and structure, whether for imaging, patient records, lab results, or other healthcare data.
- Two Main Categories of Medical Image Formats

1. Standardized Diagnostic Imaging Formats

   - DICOM (Digital Imaging and Communications in Medicine): Universally adopted for images from MRI, CT, PET, and X-ray machines.

FILE FORMAT

2. Post-Processing and Analysis Formats:

What Are: ?

When a medical image is first captured (like an MRI or CT scan), it's saved in a standardized format—usually DICOM. This format ensures compatibility across different machines and hospitals.

- Analyze: Uses a header (.hdr) and image (.img) file.
- NIfTI (Neuroimaging Informatics Technology Initiative): Common in neuroimaging. Can store both metadata and image in one file or use the two-file system.
- MINC (Medical Imaging NetCDF): Flexible and often used in research settings.

FILE FORMAT

File Configurations

1. Single-File Storage

Metadata and image data together in one file. Examples: DICOM, MINC, NIfTI

2. Two-File Storage

Metadata in one file, image data in another .Example: Analyze (.hdr for metadata, .img for image data)

Metadata : are information that describe the image. It can seem strange, but in any file format, there is always information associated with the image beyond the pixel data. This information called metadata is typically stored at the beginning of the file as a header and contains at least the image matrix dimensions, the spatial resolution, the pixel depth, and the photometric interpretation

FILE FORMAT

What is a Header?

- Medical image files don't just store pixel or voxel data; they also need information about how to interpret that data. That's where the header comes in.
- **The header is a section of the file that contains metadata about the image, such as:**

  1. Patient Information: ID, age, scan date (if allowed by privacy standards).
  2. Image Dimensions: Width, height, depth (for 3D images).
  3. Voxel Size: Real-world size of each image unit (e.g., mm^3).

FILE FORMAT

4. Acquisition Parameters: Scanner settings, modality (e.g., MRI, CT).

5.Orientation and Coordinate System: To correctly position the image in space.

For example, in the Analyze format:

- .hdr file: The header, storing all metadata.
- .img file: The actual raw image data.

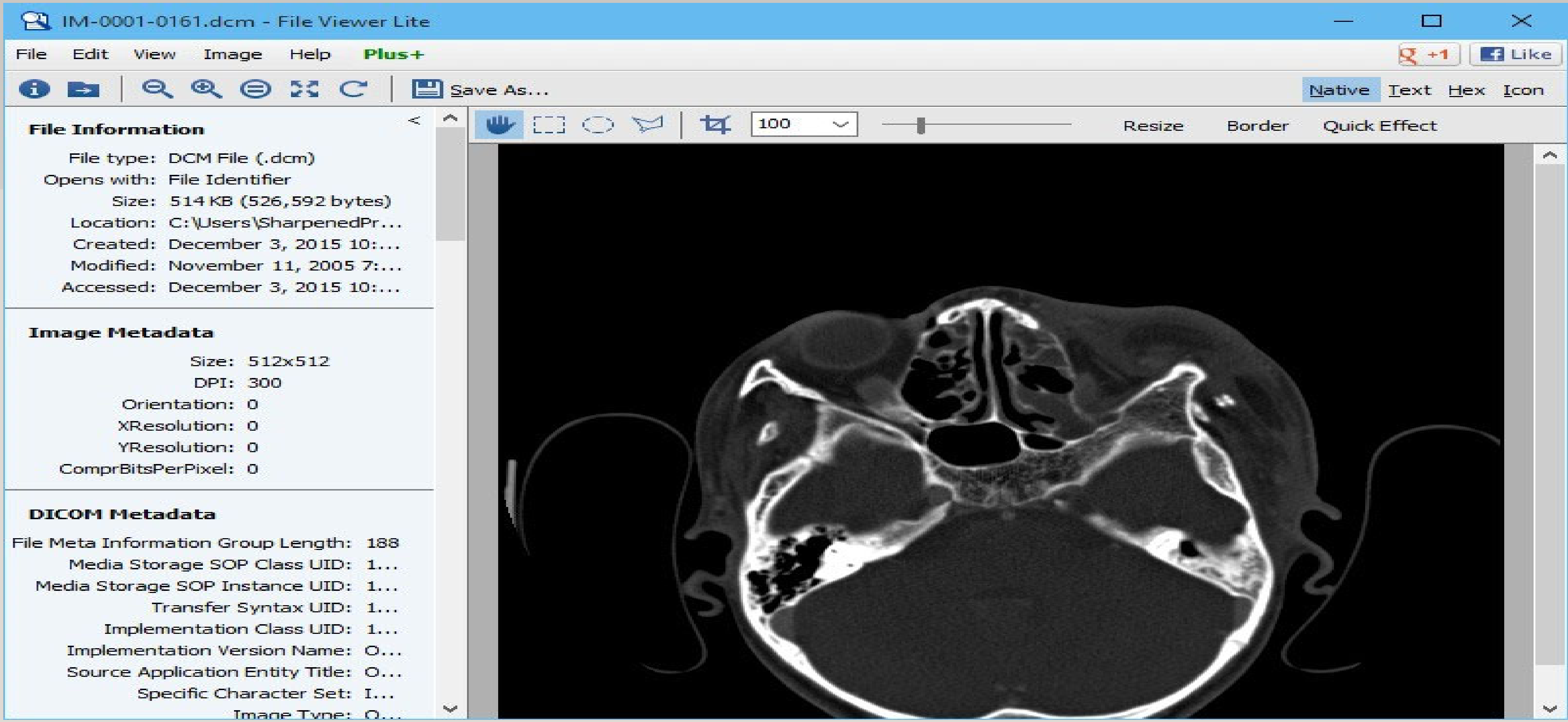
In contrast, NIfTI can store both the header and image in a single .nii file, simplifying data handling.

Summary of file formats characteristics

Format	Header	Extension	Data types
Analyze	Fixed-length: 348 byte binary format	.img and .hdr	Unsigned integer (8-bit), signed integer (16-, 32-bit), float (32-, 64-bit), complex (64-bit)
Nifti	Fixed-length: 352 byte binary format[a] (348 byte in the case of data stored as .img and .hdr)	.nii	Signed and unsigned integer (from 8- to 64-bit), float (from 32- to 128-bit), complex (from 64- to 256-bit)
Minc	Extensible binary format	.mnc	Signed and unsigned integer (from 8- to 32-bit), float (32-, 64-bit), complex (32-, 64-bit)
Dicom	Variable length binary format	.dcm	Signed and unsigned integer, (8-, 16-bit; 32-bit only allowed for radiotherapy dose), float not supported

Not all the software support all the specified data types. Dicom, Analyze, and Nifti support color RGB 24-bit; Nifti also supports RGBA 32-bit (RGB plus an alpha-channel)

[a] Nifti has a mechanism to extend the header


IM-0001-0161.dcm - File Viewer Lite
File Edit View Image Help Plus+
+1 Like
Save As...
Native Text Hex Icon
100
Resize Border Quick Effect
File Information
File type: DCM File (.dcm)
Opens with: File Identifier
Size: 514 KB (526,592 bytes)
Location: C:\Users\SharpenedPr...
Created: December 3, 2015 10:...
Modified: November 11, 2005 7:...
Accessed: December 3, 2015 10:...
Image Metadata
Size: 512x512
DPI: 300
Orientation: 0
XResolution: 0
YResolution: 0
ComprBitsPerPixel: 0
DICOM Metadata
File Meta Information Group Length: 188
Media Storage SOP Class UID: 1...
Media Storage SOP Instance UID: 1...
Transfer Syntax UID: 1...
Implementation Class UID: 1...
Implementation Version Name: O...
Source Application Entity Title: O...
Specific Character Set: I...
Image Type: O...

MEDICAL IMAGE PROCESSING

•**Image restoration** is a technique used to enhance and reconstruct medical images that may be degraded due to noise, motion blur, low resolution, or artifacts. It is crucial for improving diagnostic accuracy and image analysis in radiology, pathology, and other medical fields

•**Image restoration advantages**

Image restoration can have many advantages for medical imaging, such as enhancing the contrast and resolution of the images, making them easier to interpret and analyze. It can also reduce noise and artifacts, preserving the details and features of the images, increasing the signal-to-noise ratio and dynamic range of the images. Moreover, image restoration can reduce radiation dose and scanning time, making the images more safe and efficient.

Causes of Medical Image Degradation(Degradation Factors)

- Common Noise – Electronic or thermal noise (e.g., MRI, X-ray)
- Blur – Motion artifacts from patient movement
- Low Resolution – Poor scanning quality or upscaling needs
- Artifacts – Scanning distortions (e.g., ring artifacts in CT scans)
- Color Correction: Adjusting grayscale or color tones for better clarity.
- Lossy Compression – Degraded details due to image storage constraints

Technique	Description	Use Case
Noise Reduction (Denoising)	Removes unwanted variations (Gaussian, Poisson, Speckle noise)	MRI, X-ray, ultrasound noise reduction
Deblurring	Corrects motion blur and defocus issues	CT, PET scan motion artifacts
Super-Resolution (SR)	Increases image resolution using AI-based upscaling	Low-resolution X-ray or pathology slide enhancement
Inpainting (Missing Data Restoration)	Fills missing pixels using interpolation or AI	Reconstructing damaged or missing regions
Contrast Enhancement	Adjusts brightness and contrast for better visualization	Enhancing details in X-ray & MRI scans
Artifact Reduction	Removes scan-related distortions	Reducing metal artifacts in CT images

- Image Restoration Methods

1. **Deblurring & Motion Correction: Deblurring and Motion Correction** are essential techniques in medical image processing, especially for images affected by patient movement (e.g., MRI, CT) or acquisition artifacts. Let me walk you through these concepts and common techniques.

Blurring in medical images often occurs due to:

- Motion artifacts (e.g., patient movement)
- Out-of-focus imaging (e.g., ultrasound)
- Scanner limitations (e.g., low-resolution MRI)

Solution

- **Inverse Filtering** – Removes known blur patterns.
- **Richardson-Lucy Deconvolution** – Iterative sharpening for blurry medical scans.
- **Blind Deconvolution** – Removes unknown blurring effects.

Applications of Single Precision (32-bit) in Medical Imaging

1. **Real-Time Image Processing: CT Scans (Computed Tomography)** and **X-ray Imaging** often use **single precision** for real-time image reconstruction and processing. These applications require the ability to process large numbers of pixels quickly, and **32-bit precision** can be sufficient for tasks like image enhancement, filtering, and noise reduction.

2.Medical Image Enhancement: Techniques like contrast adjustment, edge detection, and noise removal are commonly performed using **single precision** to make sure images are processed quickly for real-time analysis during medical procedures.

3. Image Registration involves aligning different images (e.g., MRI, CT, or X-ray images) taken at different times or from different perspectives.

4.Multi-modal Image Fusion: Combining multiple imaging modalities (like CT and MRI) to create a composite image that provides more detailed information is often done using **single precision** to balance the need for speed and accuracy.

Super-Resolution (SR) & Image Enhancement

Super-resolution (SR) and image enhancement are crucial techniques in medical imaging, helping improve the quality of low-resolution scans for better diagnosis, visualization, and analysis. These techniques restore lost details, reduce noise, and improve image clarity, making medical scans like **X-rays, MRIs, CT scans, and ultrasounds** more readable.

Solution

- **Bicubic Interpolation** – Basic upscaling for low-resolution images.
- **Deep Learning (CNN, GANs)** – AI-based upscaling for detailed restoration.
- **Wavelet Transform** – Enhances high-frequency components for better clarity.

- **a) Bicubic Interpolation (Basic SR)**

A simple mathematical method that estimates pixel values in a high-resolution image by considering the weighted average of surrounding pixels.

- **Pros:**
  - Computationally fast.
  - Easy to implement.
- **Cons:**
  - Limited in detail restoration.
  - Can produce blurriness or artifacts in fine structures.

- **b) Deep Learning-Based Super-Resolution (Advanced AI SR)**
- **Types of AI-based SR models:**
  - **Convolutional Neural Networks (CNNs):** Learn patterns in medical images to restore lost details.

    SRCNN (Super-Resolution Convolutional Neural Network): One of the first CNN-based SR methods.
  - **Generative Adversarial Networks (GANs):** Generate high-resolution images by learning from real medical scans.

    ESRGAN (Enhanced Super-Resolution GAN): AI-driven model that creates highly detailed super-resolved images.
  - **Transformers & Diffusion Models:** Advanced AI models that further refine medical images.

    DIP (Deep Image Prior): Uses deep learning without needing a large dataset.

- **Advantages :**
  - Restores fine details and textures.
  - Reduces noise while maintaining sharp edges.
  - Works well for complex medical scans.
- **Limitation :**
  - Requires computational resources (GPUs).
  - Training deep learning models needs a dataset of high-quality medical images.

c) Wavelet Transform for Super-Resolution

Wavelet Transform is a powerful technique used in **medical image processing** to enhance, denoise, and improve the resolution of medical. The image is decomposed into wavelet subbands (low and high frequencies). Higher frequency details are enhanced, and an inverse wavelet transform reconstructs the improved image.

Enhancing MRI, CT, and X-ray images by sharpening fine structures.

Wavelet Transform (WT) is a mathematical method that decomposes an image into different **frequency components (high and low frequencies)**. This allows selective enhancement of **edges, textures, and important medical structures** while reducing unwanted noise.

Advantages:

Preserves small anatomical details.

Avoids over-smoothing compared to other methods like bicubic interpolation.