Lecture 21
Working with Diagnostic Medical Images (in MATLAB)

Lecture 21 #goals

Medical Images

- Imaging for Medical Diagnostic
- DICOM Data Format
- Commercial Software
- MATLAB DICOM tools (Image Processing Toolbox)

MATLAB Graphics Properties

- Property Browser
- read/write properties

3D Data Visualization

- Plotting Slices
- Plotting Isosurfaces

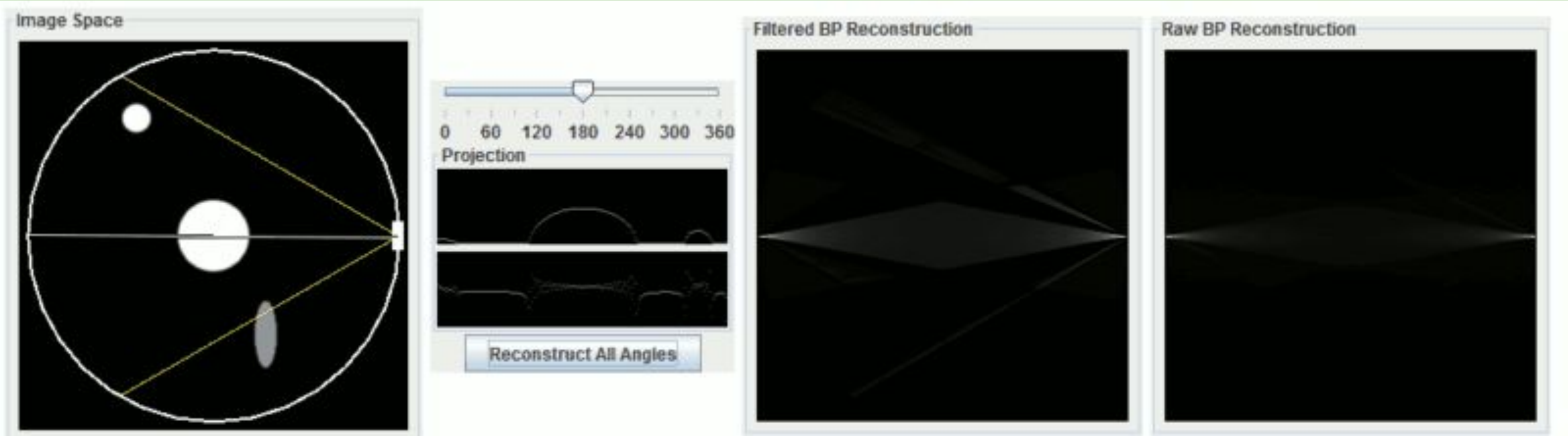
Imaging for Medical Diagnostics

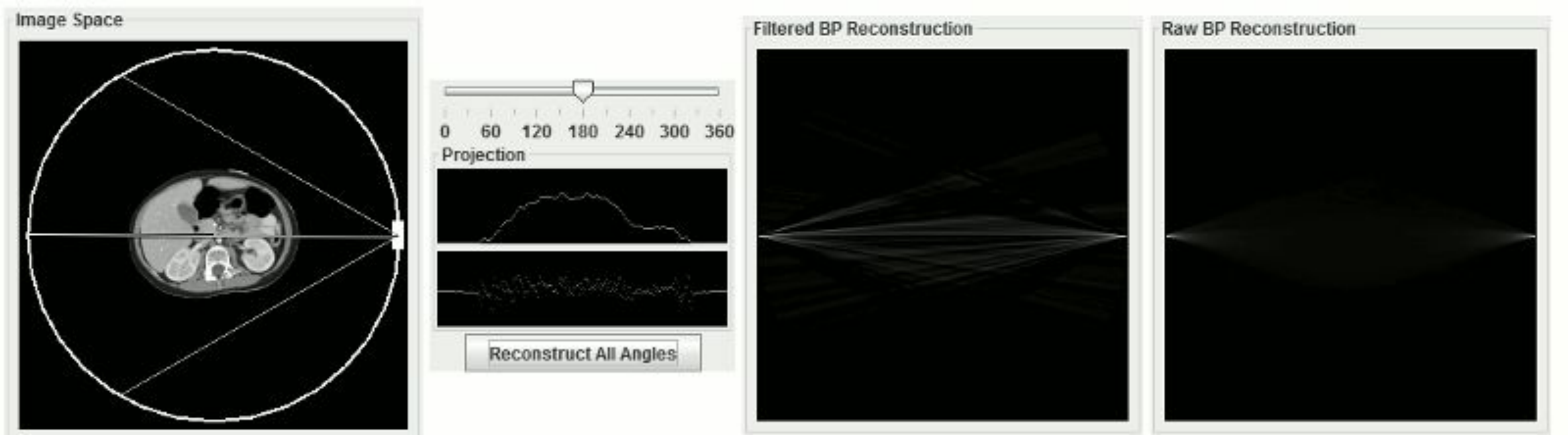
Many types of diagnostic medical imaging machines are used in practice. The most common examples include:

- X-ray
- computed tomography (CT)
- magnetic resonance imaging (MRI)
- positron emission tomography (PET)
- ultrasound

Imaging for Medical Diagnostics

CT scans generate 'volumetric' information by applying numerical computations ('backpropagation') on a series of x-ray images taken at different angles and locations.

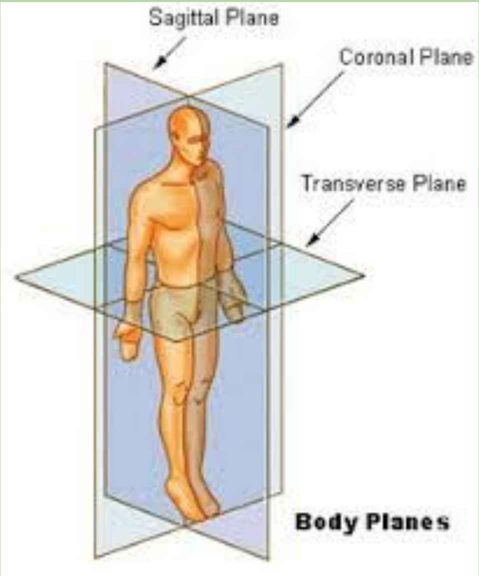




http://xrayphysics.com/ctsim.html

Imaging for Medical Diagnostics

Captured "images" can be 2D, 3D, 4D, …



All medical images have key characteristics:

- subject orientation/coordinates
- image resolution/accuracy
- tissue density to image intensity mapping
- total contrast/dynamic range
- patient information (*sensitive metadata*)

Digital Imaging and Communications in Medicine (DICOM) Standard

Joint project by the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA)

- v1.0 published in 1985
    - X-Rays
    - CT scans
- v3.0 is the current version of the standard & supports numerous medical imaging data types
    - MRI scans
    - Dentistry
    - Surgical planning
    - 3D ultrasound
    - 3D printed instrument files
    - and many more...

https://www.dicomstandard.org/current/

DICOM Standard Images

Pixel intensity values are different for each imaging type

- X-ray (intensity = gamma ray absorption level)
  - Bones => light
  - Soft tissues => dark
- MRI (intensity = frequency response of an RF pulse)

Image contrast, or the intensity difference between tissue types, is needed to show features of interest

Each file contains a 2D “slice” of imaging data

- 8-bit (0, 255) or 16-bit (0, 65,535) levels
- RGB (MxNx3) or Grayscale (MxNx1)

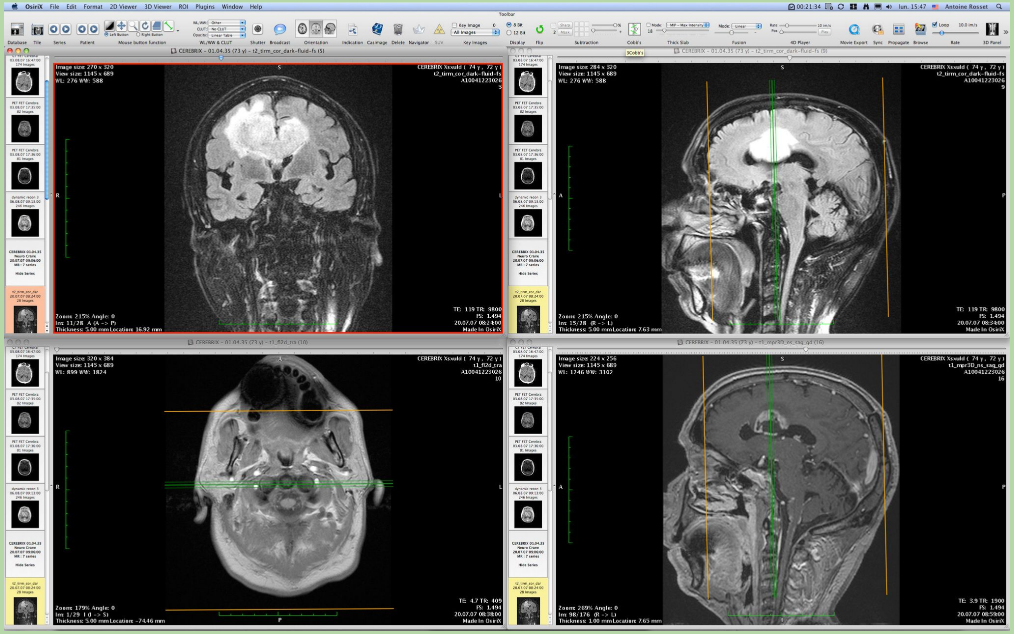
Commercial DICOM Software

Many commercial software packages exist for viewing and editing DICOM standard images

- These packages are primarily developed for the medical community (radiologists, general practitioners, patients, etc.)

Examples:

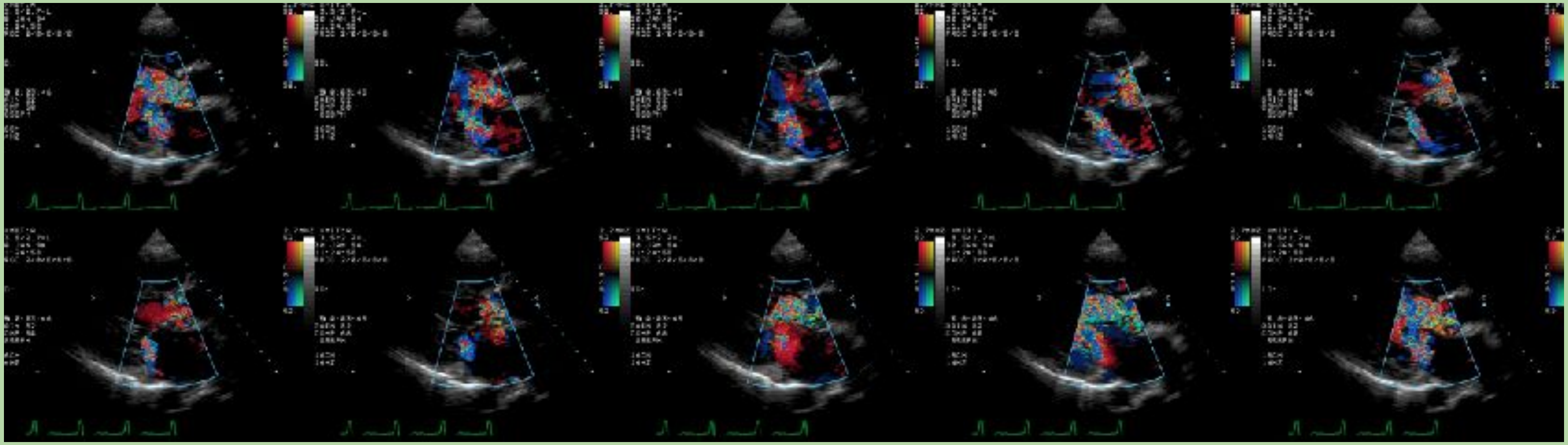
- OsiriX for OS X
  - free "Lite" version
- MicroDicom for Windows
  - free viewer



DICOM Images in MATLAB

MATLAB supports DICOM import/export since 2006

- Part of the Image Processing Toolbox (optional installation package)
- Reads in DICOM standard files
- Writes 3 types of DICOM files (Secondary capture, MRI, CT)



DICOM ultrasound “snapshots” plotted in MATLAB
Source: https://www.mathworks.com/help/images/ref/dicomread.html

DICOM Images in MATLAB

`dicomdisp``(filename)` - Displays DICOM file structure on command line

`dicominfo``(filename)` - Reads metadata from DICOM file into struct

`X =` **`dicomread`**`(filename)` - Reads a DICOM image

`[X, colormap, alpha, overlaps] =` **`dicomread`**`(filename)`
Also reads the colormap, alpha channel, and any overlays, if they exist

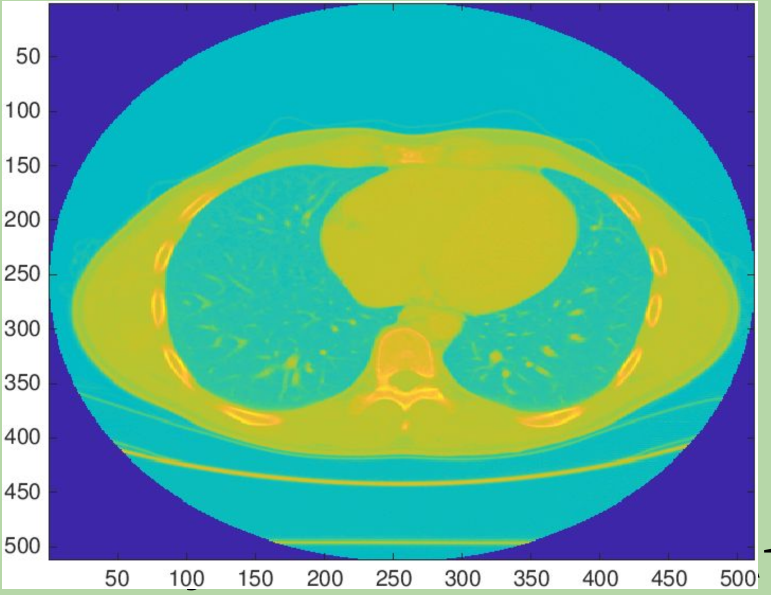
`dicomwrite``(X, filename)` - Write images as DICOM files

Note: `dicomreadVolume` *exists, but don't use it for homework.*

DICOM Images in MATLAB

Once the DICOM image is read into a variable, we can treat it as any normal image

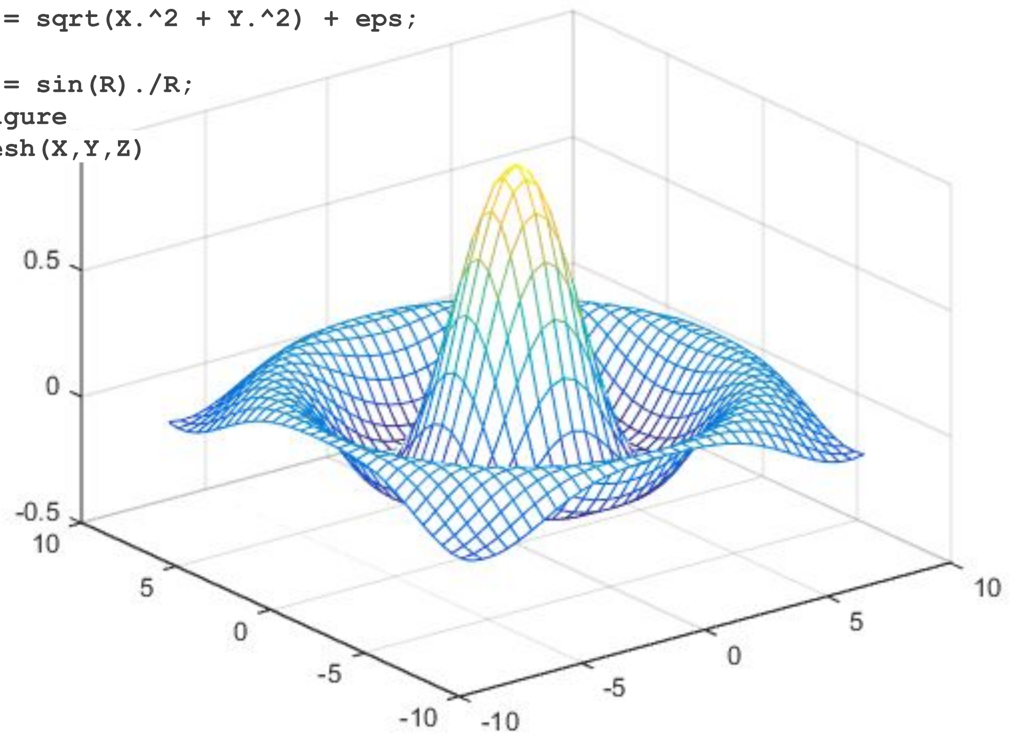
```
>>  x = dicomread('IM-0002-0003.dcm');
>>  imagesc(x)
```




```
>>  whos x
   Name      Size                                ttributes
   x         512x512       524288    int16
```

MATLAB Graphics Properties

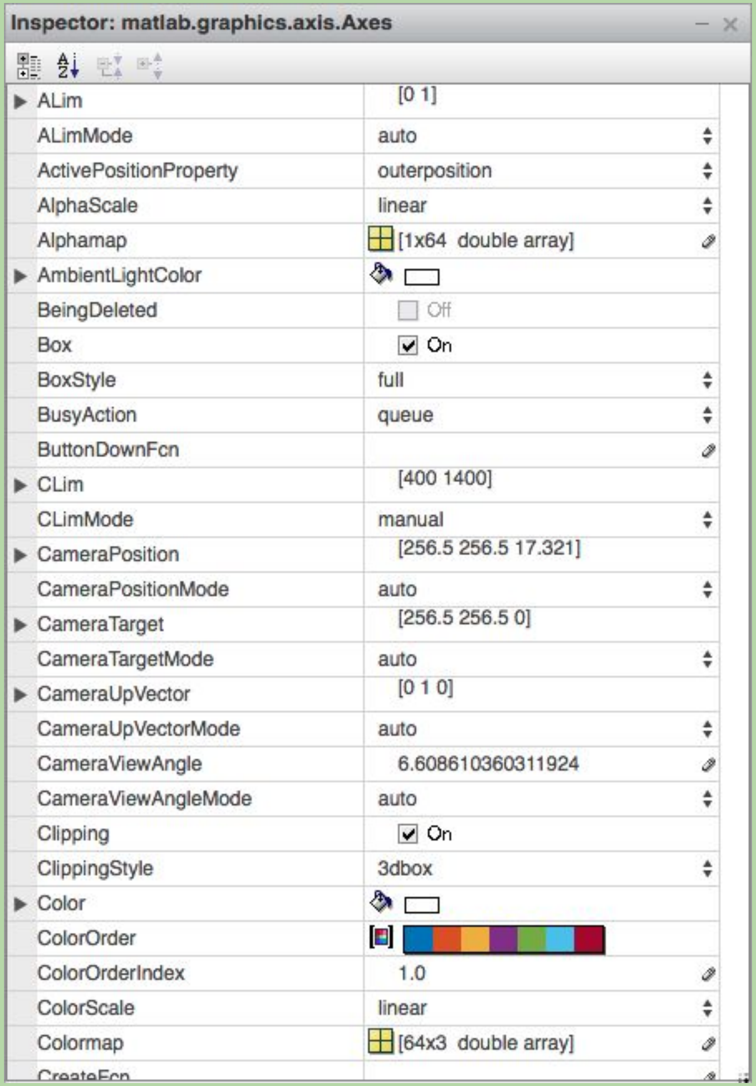
```
[X,Y] = meshgrid(-8:.5:8);
R = sqrt(X.^2 + Y.^2) + eps;

Z = sin(R)./R;
figure
mesh(X,Y,Z)
```



MATLAB Graphics Objects

Every graphics object (figure, axis, surface, line, light, etc.) has a set of properties.

These properties can be viewed or modified using the Property Inspector.



MATLAB Graphics Objects

Alternatively, we can access properties as object attributes

```
>> fh = figure;
>> fh.Color = [1 1 1]   % set background to white

>> x = plot(randn(1000,1));
>> x.LineStyle = ':';
>> x.LineWidth = 2;
```

In older releases of MATLAB we can use ‘get’ and ‘set’ commands.

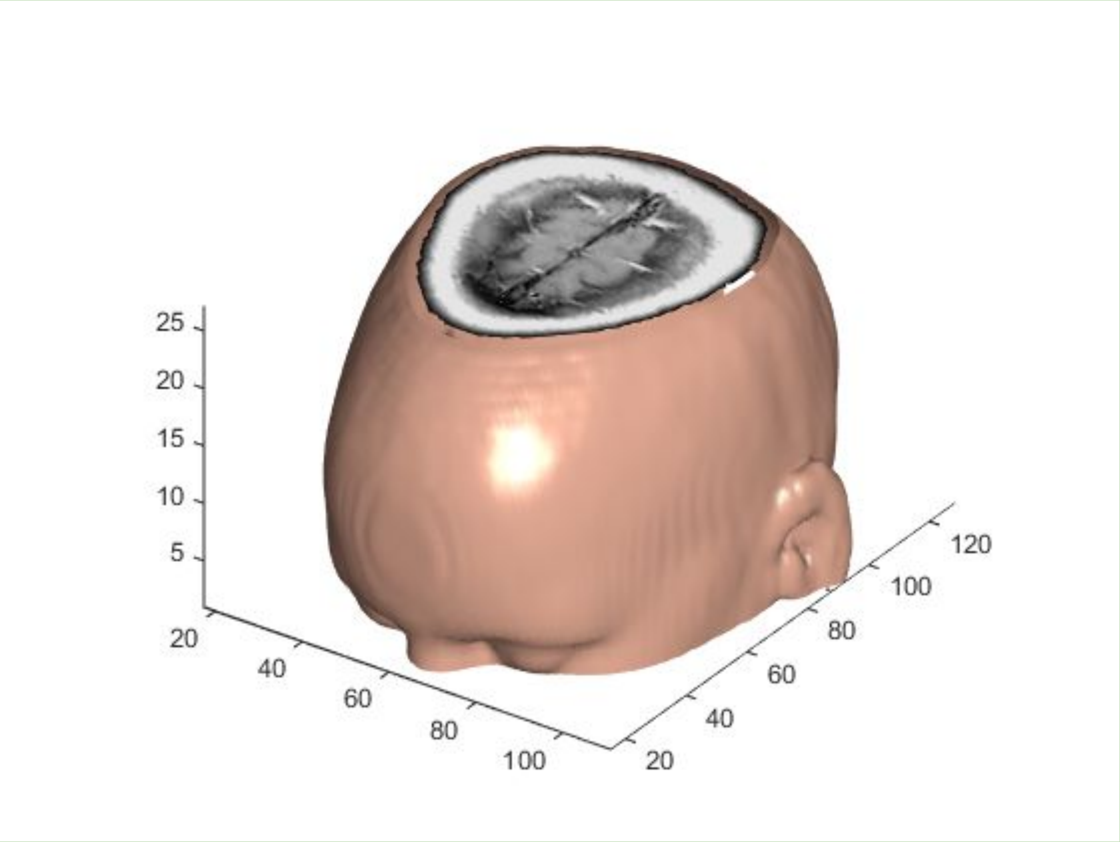
```
>> x = get(fh, 'XScale');
>> set(fh, 'XScale', 'log')
```

MATLAB Graphics Objects

Without the object handle, you will need to use ‘gca’, ‘gcf’, or ‘gco’ (“Get current (axis|figure|object)”). These commands retrieve the handle of the most recently accessed axis, figure, or object.

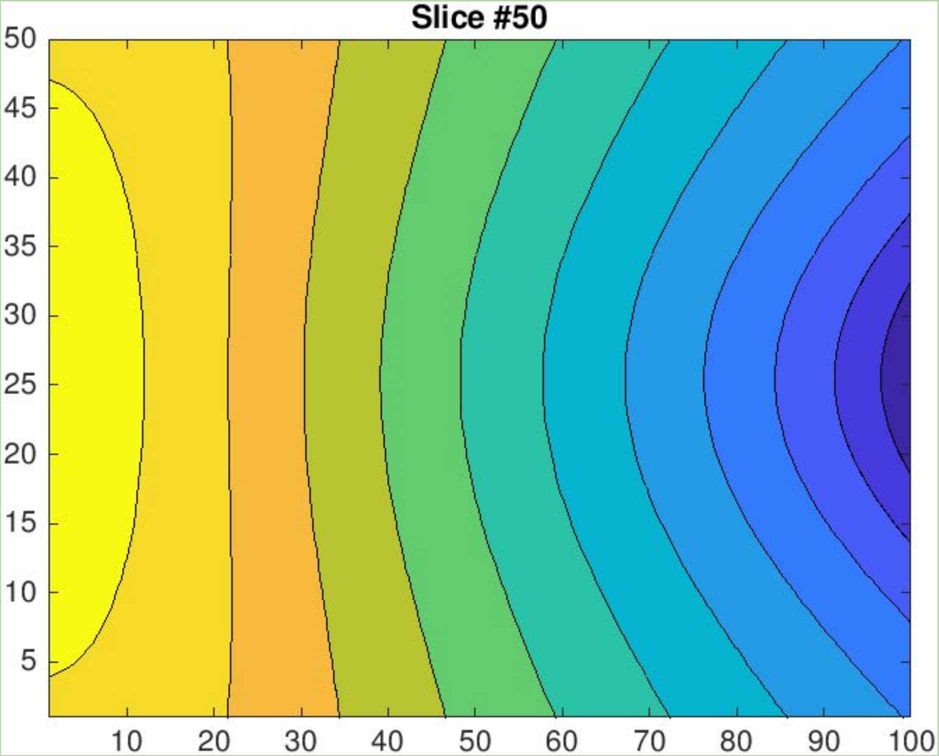
```
>> x = get(gco, 'XScale');
>> set(gcf, 'Position', [1 1 640 480])
```

3D Data Visualization



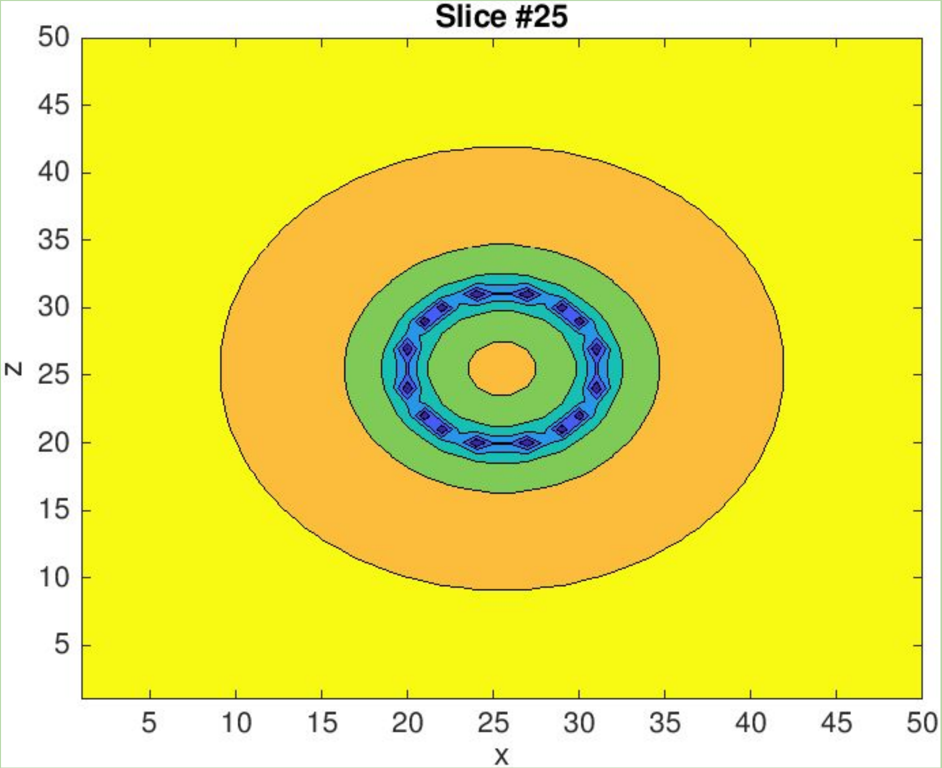
3D Volumetric Data in MATLAB

```
x = flow(50);

%% plotting X-Y axis
fh = figure;
for n = 1:size(x,3)
    xslice = x(:,:,n);
    contourf(xslice);

    xlabel('x')
    ylabel('y')
    title(sprintf('Slice #%d',n))

    pause(0.1)
end
```



3D Volumetric Data in MATLAB

```
x = flow(50);

%% plotting X-Z axis
fh = figure;
for n = 1:size(x,2)
     xslice = squeeze(x(:,n,:));
     contourf(xslice);

     xlabel('x')
     ylabel('z')
     title(sprintf('Slice #%d',n))

     pause(0.1)
end
```



squeeze is needed to reduce dimensionality: Mx1xN => MxN

“slicing” into 3D Matrices

Selecting sub-volumes can be done with standard indexing

```
data = flow;     % load ‘flow’ dataset

xIdx = 20:40;
yIdx = 5:2:end;
zIdx = 10:35;

subdata = data(xIdx,yIdx,zIdx);
```

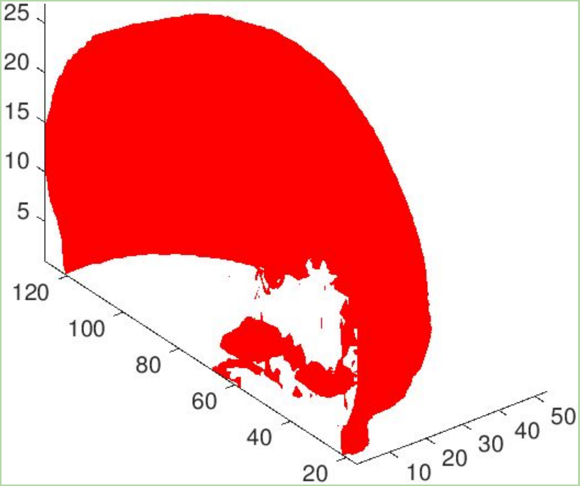
3D Volumetric Data in MATLAB

```
>>  load mri           % load built-in MRI data set
>>  whos
Name    Size           Bytes   Class   Attributes
D       128x128x1x27   442368  uint8
map     89x3           2136    double
siz     1x3            24      double

>>  D = squeeze(D);    % remove 'singleton' dimension
>>  D(:,1:60,:) = [];  % delete half of data about y-axis
>>  whos
Name    Size           Bytes   Class   Attributes
D       128x68x1x27    235008  uint8
map     89x3           2136    double
siz     1x3            24      double
```

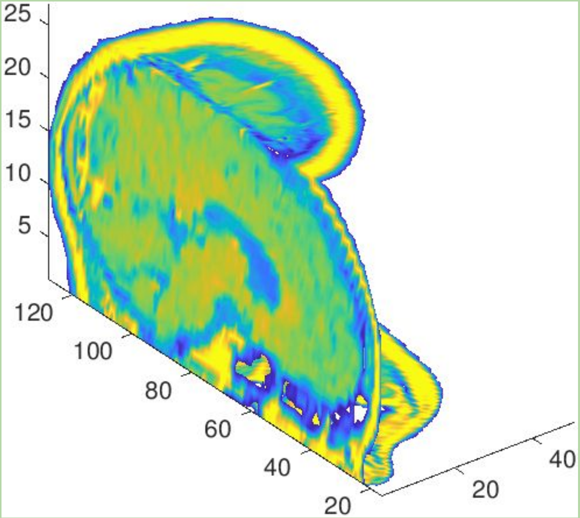
3D Volumetric Data in MATLAB

```
%% plot volumetric surfaces

% create 'patch' objects for each surface
thresh = 5;      % pick a threshold level
p1 = patch(isosurface(D, thresh),'FaceColor','red','EdgeColor','none');
p2 = patch(isocaps(D, thresh),'FaceColor','interp','EdgeColor','none');
```

p1 (isosurface)



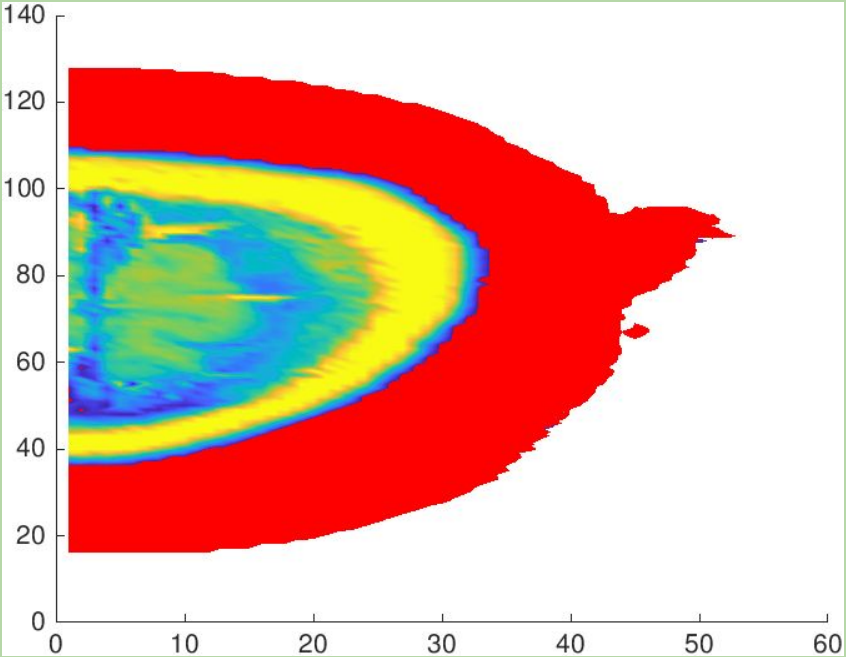
p2 (isocaps)



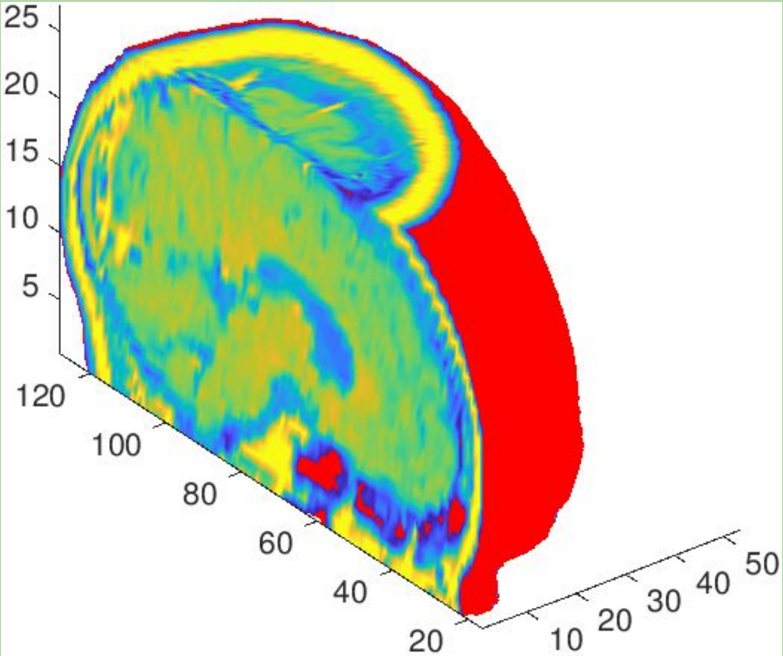
3D Volumetric Data in MATLAB

```
%% manipulate view
view(3)
axis tight
daspect([1,1,.4])
```

default view



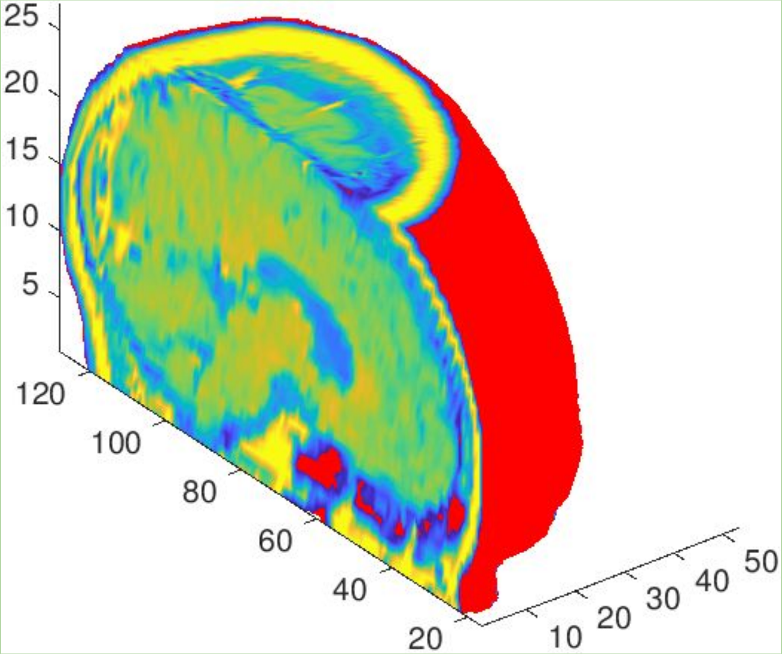
manipulated view



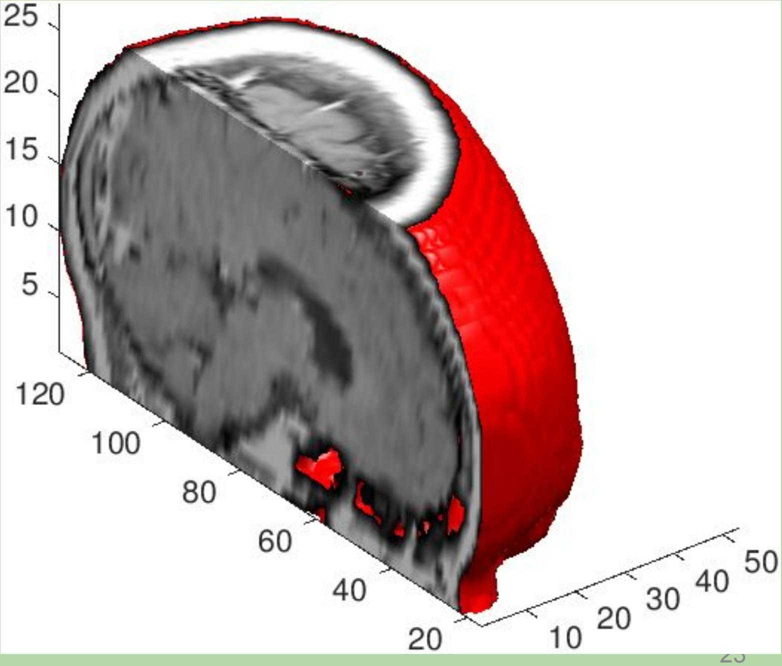
3D Volumetric Data in MATLAB

```
%% modify color and lighting effects
colormap(gray(100))
camlight left
camlight
lighting gouraud
```

default color/lighting



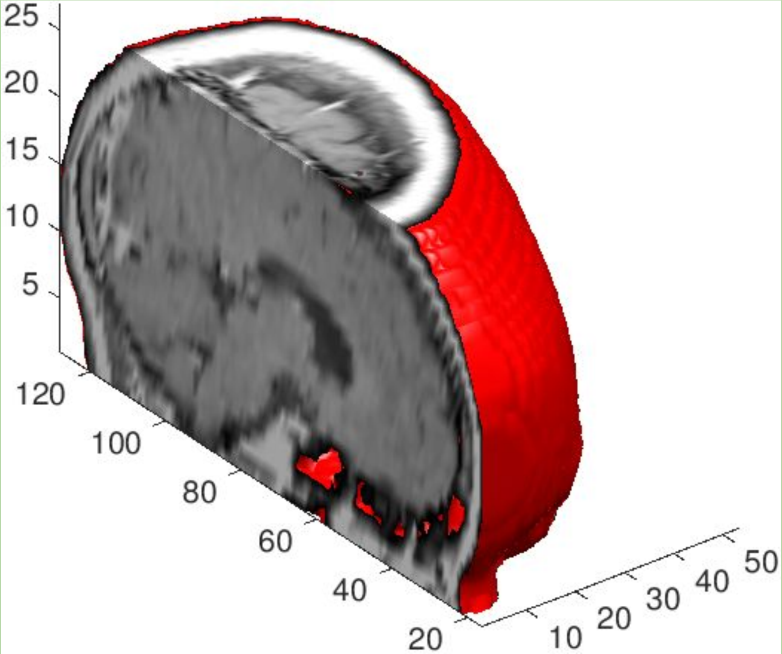
modified color/lighting



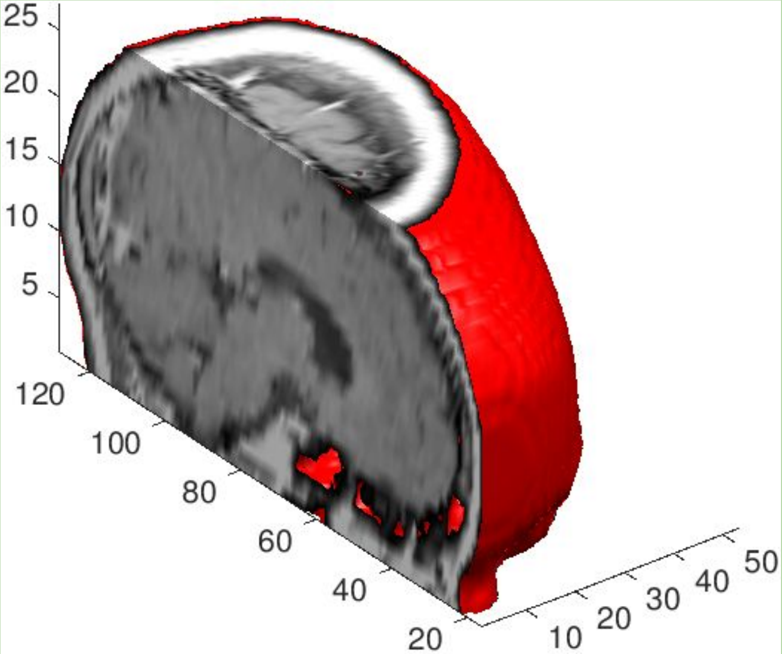
3D Volumetric Data in MATLAB

```
%% smooth out isosurface by computing normals from data
isonormals(D,p1)
```

default isonormals ('Triangular')



modified isonormals (computed)



isonormals generally creates a smoother surface finish

3D Volumetric Data in MATLAB

FV = **isosurface**(X,Y,Z,V,ISOVALUE) computes **isosurface geometry** for data V at isosurface value ISOVALUE.

FVC = **isocaps**(X,Y,Z,V,ISOVALUE) computes **isosurface end cap geometry** for data V at isosurface value ISOVALUE

N = **isonormals**(X,Y,Z,V,VERTICES) computes the **normals of isosurface vertices** VERTICES by using the **gradient of the data V**.

3D Volumetric Data in MATLAB

Generate the 3D coordinate system (or assume default unit spacing)

```
>>  [XX,YY,ZZ] = meshgrid(...)
```

MATLAB can also handle non-uniform grids, but requires user to create 3D grid manually

Transformations of 3D Matrices

Affine transformations (translation and rotation of data) can be performed by modifying the x, y, z coordinates

Translation along x-axis

```
X = X + deltaX;
```

Translation along y-axis

```
Y = Y + deltaY;
```

Translation along z-axis

```
Z = Z + deltaZ;
```

Transformations of 3D Matrices

Rotation about X-axis:

```
X = X;
Y = Y*cos(theta) - Z*sin(theta);
Z = Y*sin(theta) + Z*cos(theta);
```

Rotation about Y-axis:

```
X = X*cos(theta) + Z*sin(theta);
Y = Y;
Z = Z*cos(theta) - X*sin(theta);
```

Rotation about Z-axis:

```
X = X*cos(theta) - Y*sin(theta);
Y = X*sin(theta) + Y*cos(theta);
Z = Z;
```

3D Volumetric Data in MATLAB

Building a 3D volumetric image from 2D medical images requires stacking each image. The (x,y,z) coordinates will need to be tracked carefully.

1) pre-initialize the 3D matrix (optional, for efficiency)
```
V = zeros(M,N,numel(files));
```
2) import each 2D medical image
```
x = dicomread(filename);
```
3) save each image to a slice in the 3D matrix
```
V(:,:,n) = x;
```

`V(x,y,z)` => single pixel (“voxel” in 3D) at index x,y,z

Note: verify the size of each image to make sure it is M x N!

#puppiesrule