



Introduction to Data, Signal, and Image Analysis with MATLAB®

Lesson 4: Image Representation
in Matlab



Jack Noble, Introduction to Data, Signal, and Image Analysis with MATLAB®

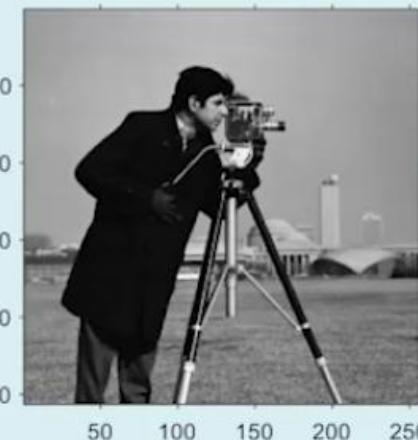


Image is a 2D matrix of “pixels”

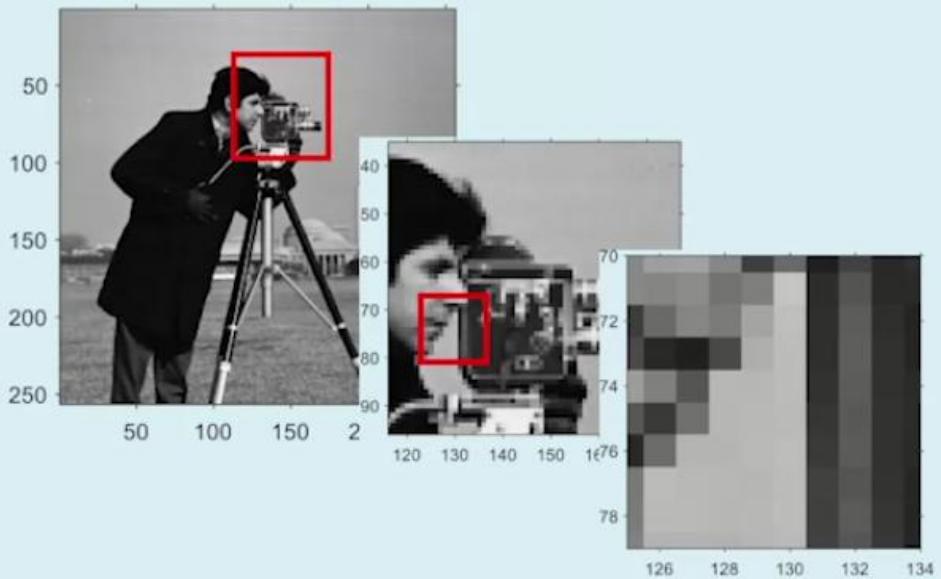
Pixels: Picture elements

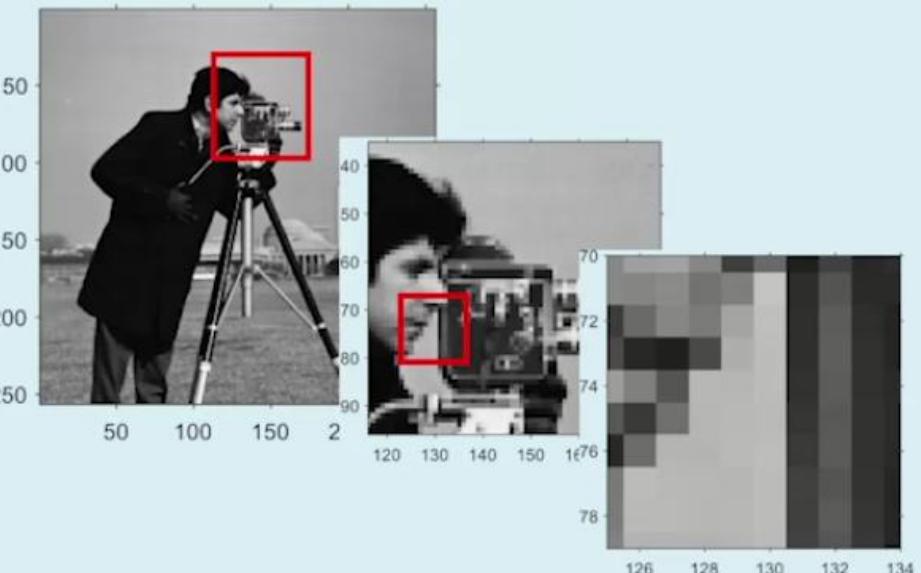
```
>> img = imread('cameraman.tif');
```

```
>> size(img)
```

```
ans =
```

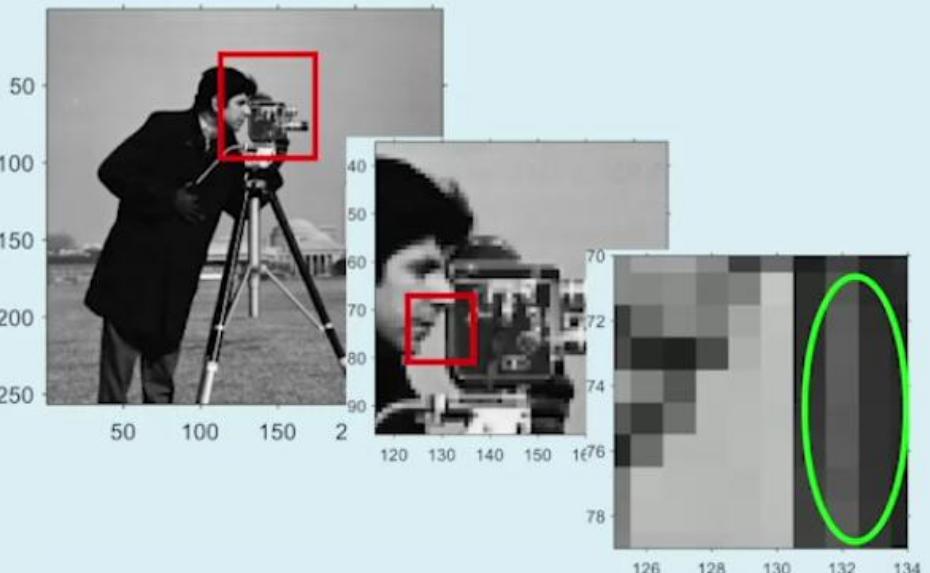
```
256 256
```





10x10 `uint8` matrix

136	158	162	135	63	106	32	66	40	47
136	133	140	115	126	196	45	84	42	42
61	106	134	123	164	191	47	92	46	37
74	40	32	73	174	188	47	94	49	38
157	128	85	183	182	187	50	92	49	43
88	58	111	182	184	186	54	89	50	44
40	108	181	181	185	189	58	91	50	42
121	187	184	183	182	188	65	85	51	38
124	185	185	182	183	188	64	91	53	39
130	179	180	178	181	186	66	86	57	38



10x10 `uint8` matrix

136	158	162	135	63	106	32	67	40	47
136	133	140	115	126	196	45	84	42	42
61	106	134	123	164	191	47	92	46	37
74	40	32	73	174	188	47	94	49	38
157	128	85	183	182	187	50	92	49	43
88	58	111	182	184	186	54	89	50	44
40	108	181	181	185	189	58	91	50	42
121	187	184	183	182	188	65	85	51	38
124	185	185	182	183	188	64	81	53	39
130	179	180	178	181	186	66	86	57	38

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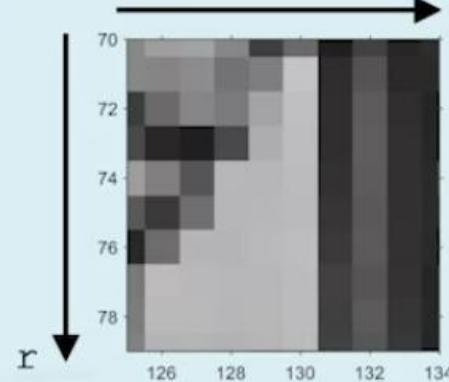
>> img(1:r, 1:c)

c
(2nd dimension)

10x10 `uint8` matrix

136	158	162	135	63	106	32	66	40	47
136	133	140	115	126	196	45	84	42	42
61	106	134	123	164	191	47	92	46	37
74	40	32	73	174	188	47	94	49	38
157	128	85	183	182	187	50	92	49	43
88	58	111	182	184	186	54	89	50	44
40	108	181	181	185	189	58	91	50	42
121	187	184	183	182	188	65	85	51	38
124	185	185	182	183	188	64	91	53	39
130	179	180	178	181	186	66	86	57	38

r
(1st dimension) c



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CURRENT FOLDER

WORKSPACE

Name	Value	Size	Class
c	15	1x1	double
i	10	1x1	double
img	10x15 double	10x15	double
J	15	1x1	double
r	10	1x1	double

COMMAND WINDOW

1	14	21	28	35	42	49	56	63	70	77	84	91	98	105
8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
9	18	27	36	45	54	63	72	81	90	99	108	117	126	135
10	20	30	40	50	60	70	80	90	100	110	120	130	140	150

```
>> imagesc(img)
```

```
>> |
```

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CURRENT FOLDER

WORKSPACE

Name

c

15

1x1

double

Value

i

10

1x1

double

Size

img

10x15 double

10x15

Class

J

15

1x1

double

r

10

1x1

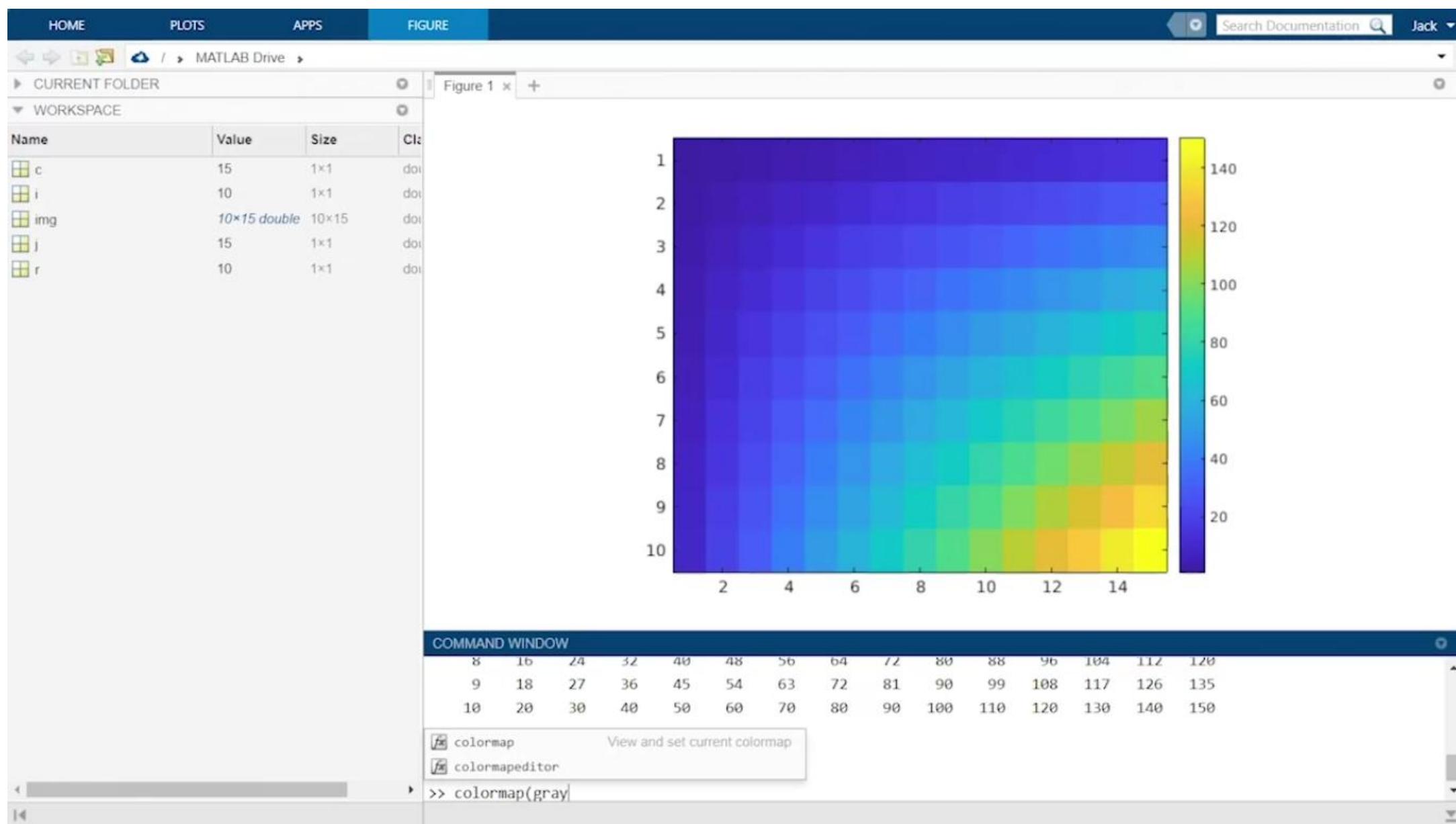
double

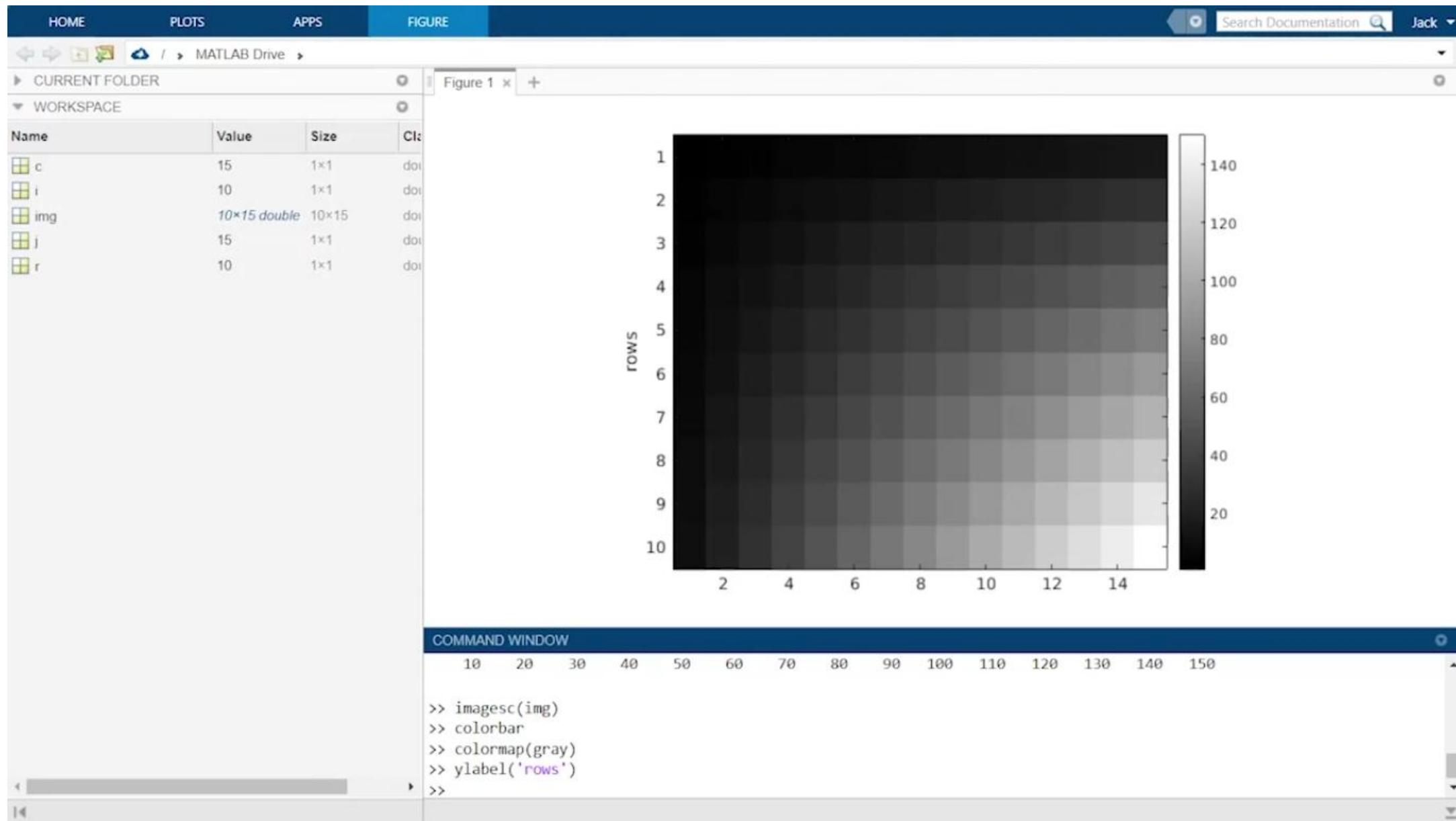
```
>> r = 10;  
>> c = 15;  
>> img = zeros(r,c);  
>> for i=1:r  
    for j=1:c  
        img(i,j) = i*j;  
    end  
end  
>> img
```

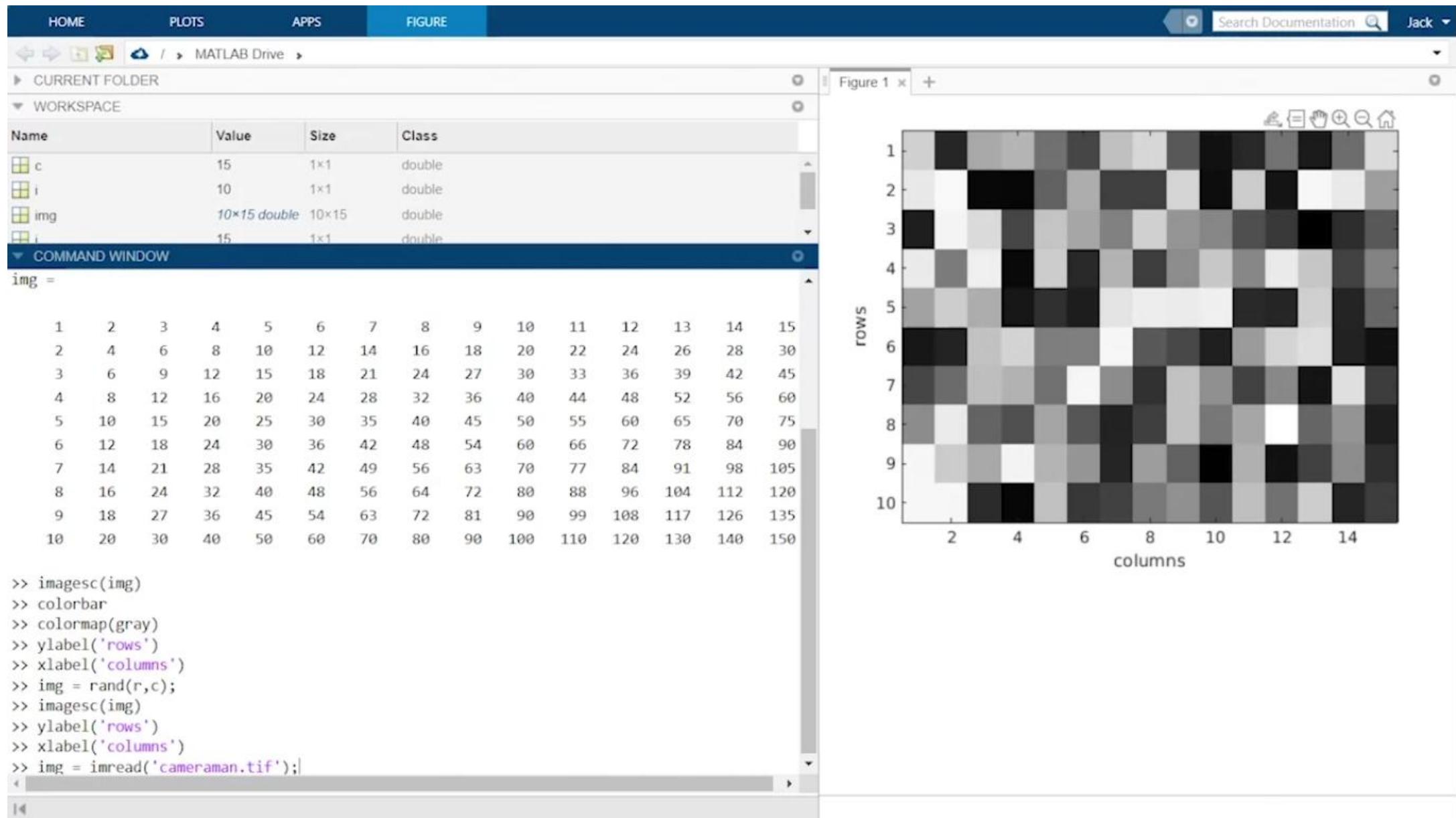
img =

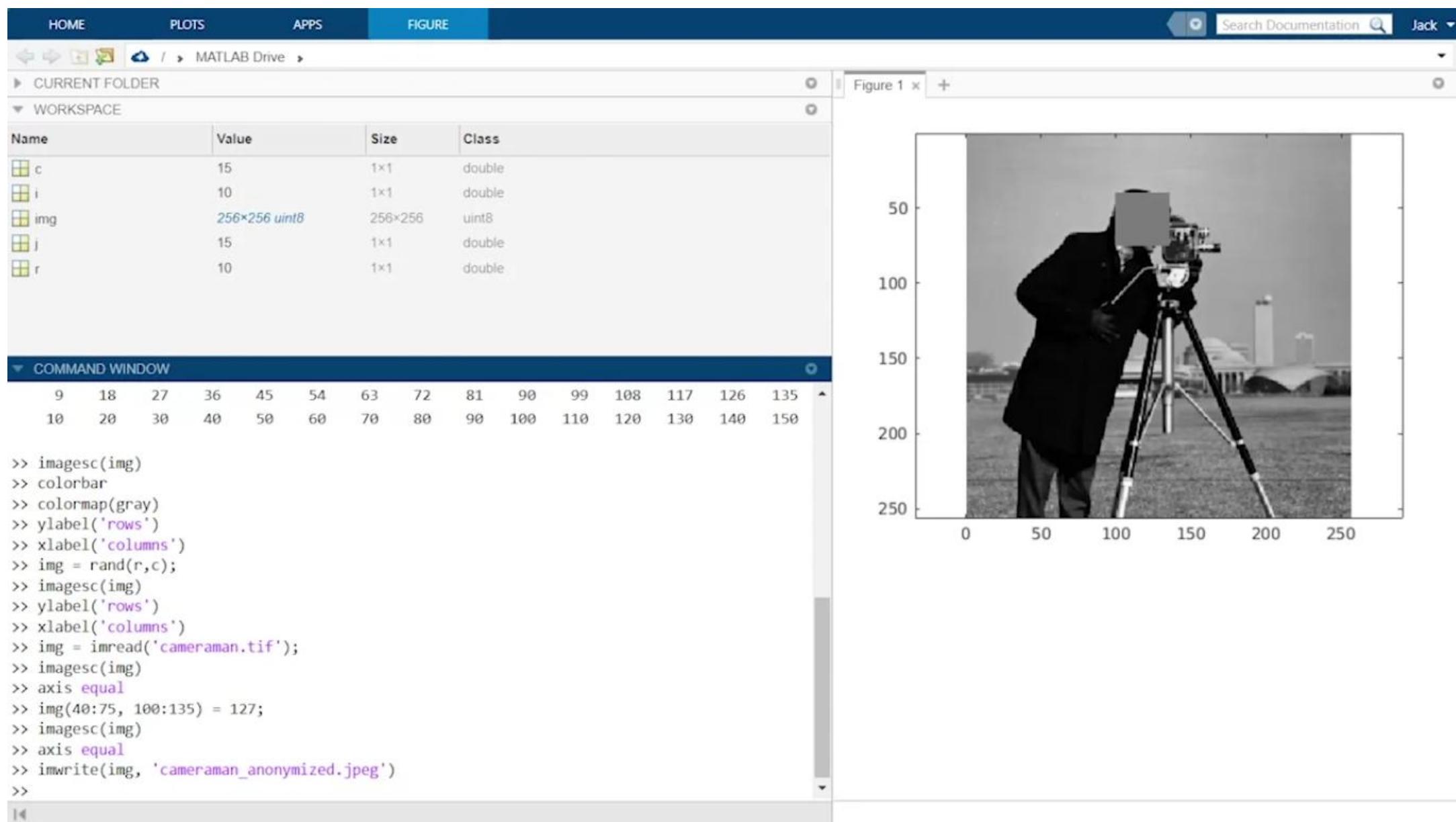
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
3	6	9	12	15	18	21	24	27	30	33	36	39	42	45
4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
7	14	21	28	35	42	49	56	63	70	77	84	91	98	105
8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
9	18	27	36	45	54	63	72	81	90	99	108	117	126	135
10	20	30	40	50	60	70	80	90	100	110	120	130	140	150

>>











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00:12 / 21:31
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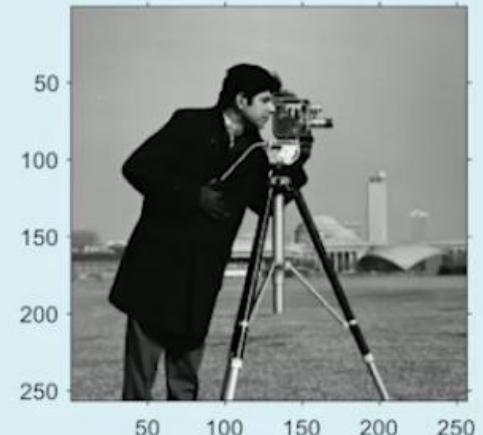
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Lesson 4.2 Image Resampling

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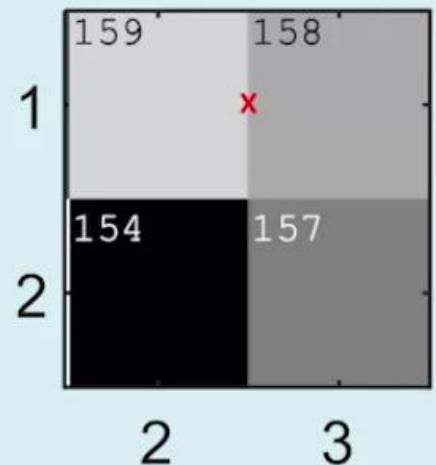
```
>> img = imread('cameraman.tif');
```



```
interp2(double(img{r x c}), {[1,c]}, {[1,r]})
```



```
img(1:2,2:3)
```



```
>> interp2(double(img), 2.5, 1)
```

```
ans =
```

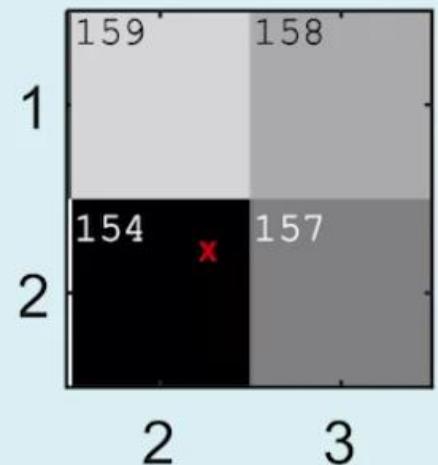
```
158.5
```



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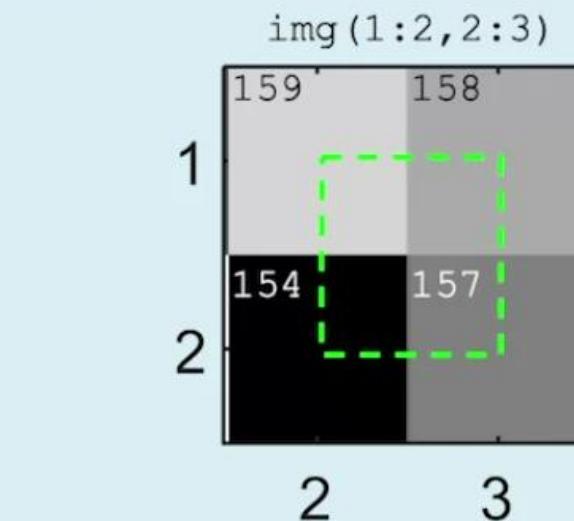
img(1:2,2:3)



```
>> interp2(double(img), 2.25, 1.75)
```

```
ans =
```

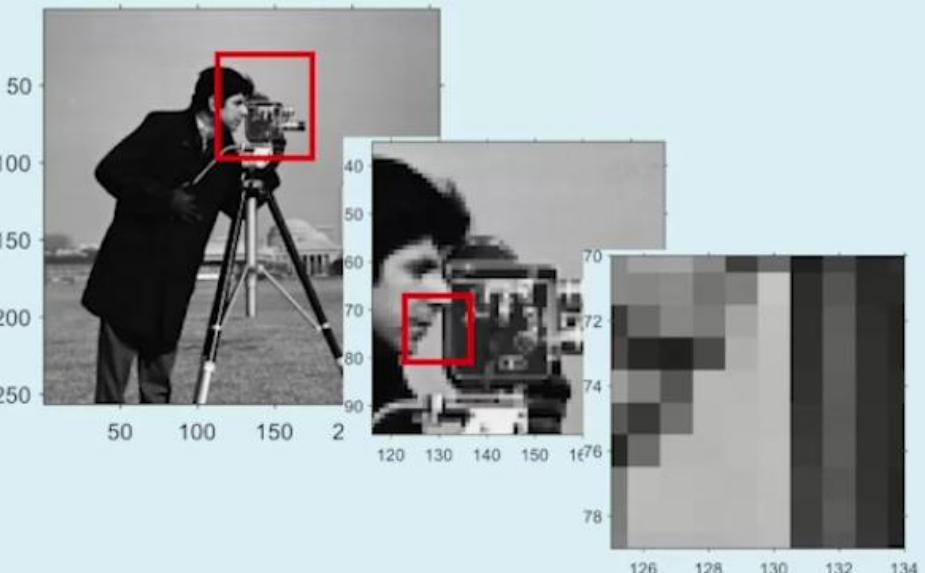
```
155.75
```



```
>> interp2(double(img), ...  
[2, 2.5, 2.5, 2.5], ...  
[1, 1, 2, 1.5])
```

ans =

159.0 158.5 155.5 157.0

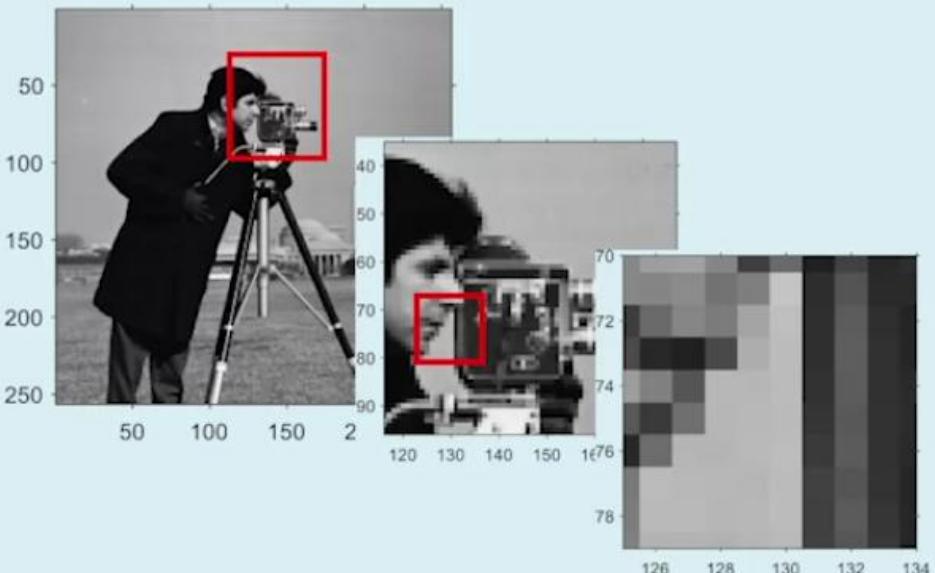


```
>> [C,R] = meshgrid(125:0.1:134, 70:0.1:79);  
>> R(1:5,1:5)  
ans =  
  
70.0000    70.0000    70.0000    70.0000    70.0000  
70.1000    70.1000    70.1000    70.1000    70.1000  
70.2000    70.2000    70.2000    70.2000    70.2000  
70.3000    70.3000    70.3000    70.3000    70.3000  
70.4000    70.4000    70.4000    70.4000    70.4000
```



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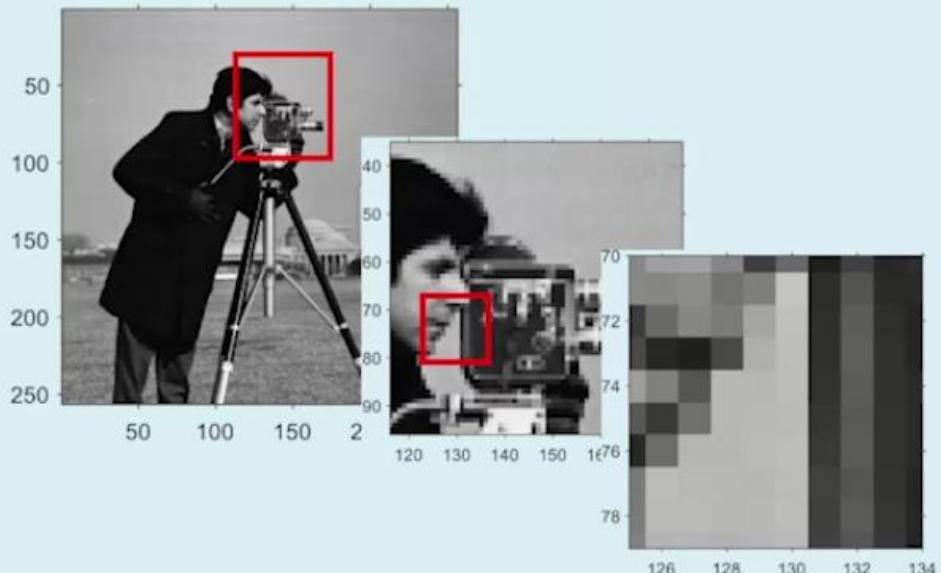
```
>> [C,R] = meshgrid(125:0.1:134, 70:0.1:79);  
>> C(1:5,1:5)  
ans =  
  
125.0000 125.1000 125.2000 125.3000 125.4000  
125.0000 125.1000 125.2000 125.3000 125.4000  
125.0000 125.1000 125.2000 125.3000 125.4000  
125.0000 125.1000 125.2000 125.3000 125.4000  
125.0000 125.1000 125.2000 125.3000 125.4000
```

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```
>> [C,R] = meshgrid(125:0.1:134, 70:0.1:79);  
>> img_upsample = interp2(double(img),C,R,'linear');
```



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WORKSPACE

Name	Value	Size
C	1000×1500...	1000×1500
c	256	1×1
img	256×256 ui...	256×256
nc	1500	1×1
nr	1000	1×1
R	1000×1500...	1000×1500
r	256	1×1
upsimg	1000×1500...	1000×1500

```
>> img = imread('cameraman.tif');
>> nr = 1000;
>> nc = 1500;
>> [r,c] = size(img);
>> [C,R] = meshgrid(1:(c-1)/(nc-1):c, 1:(r-1)/(nr-1):r);
>> upsimg = interp2(double(img), C, R);
>> |
```

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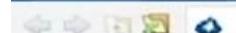
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WORKSPACE

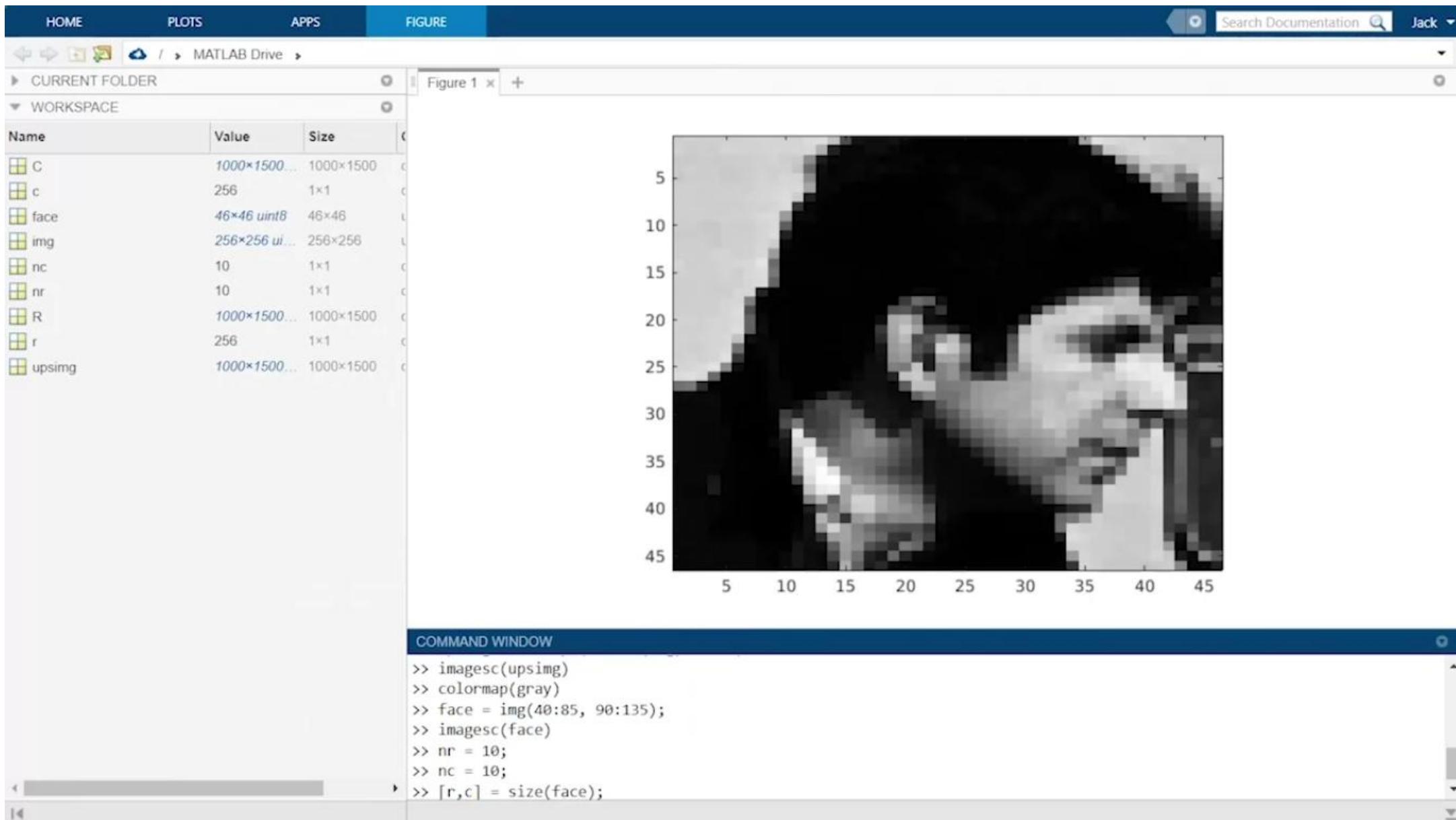
Name	Value	Size
C	1000×1500...	1000×1500
c	256	1×1
img	256×256 ui...	256×256
nc	1500	1×1
nr	1000	1×1
R	1000×1500...	1000×1500
r	256	1×1
upsimg	1000×1500...	1000×1500

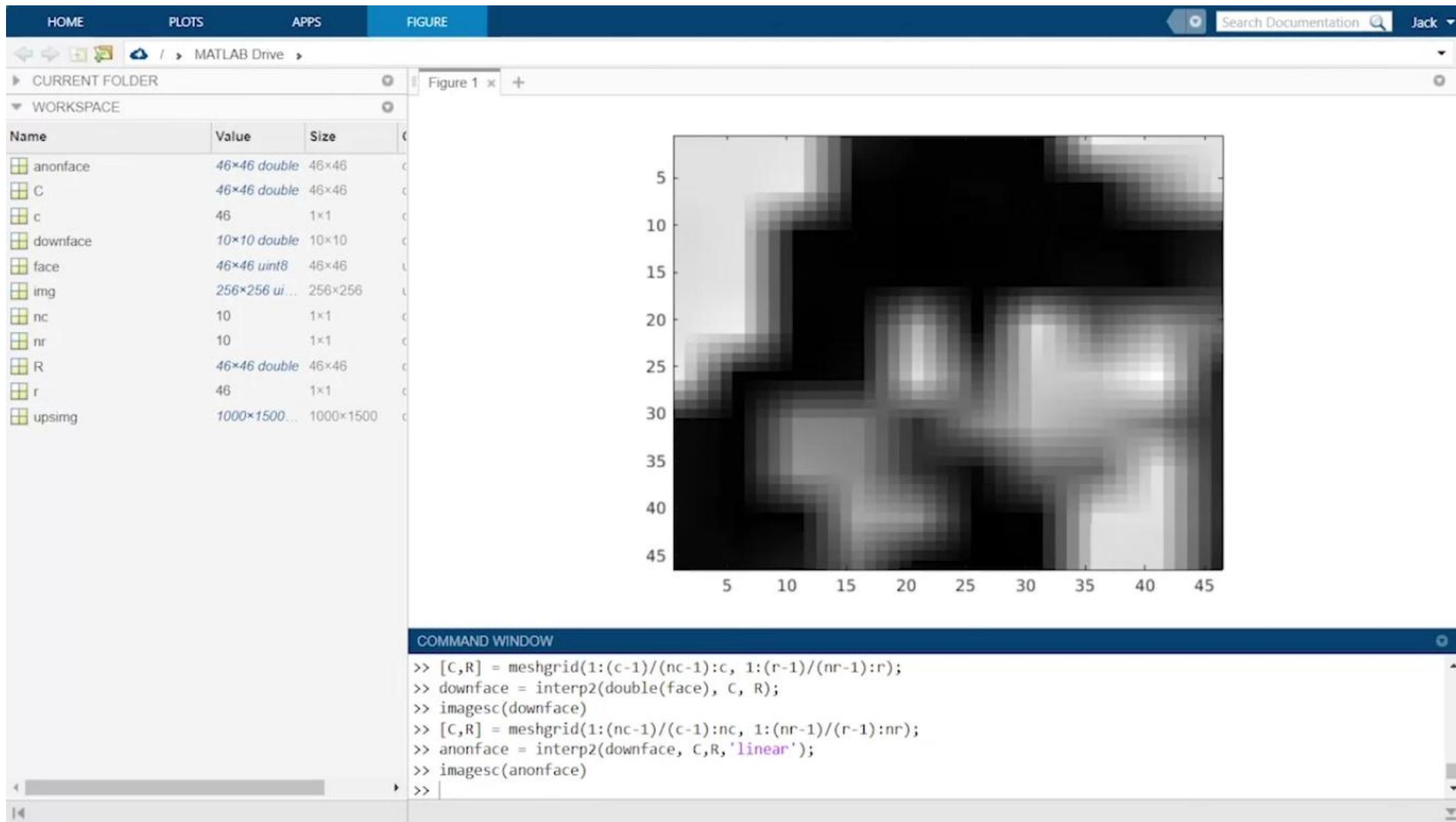
Figure 1

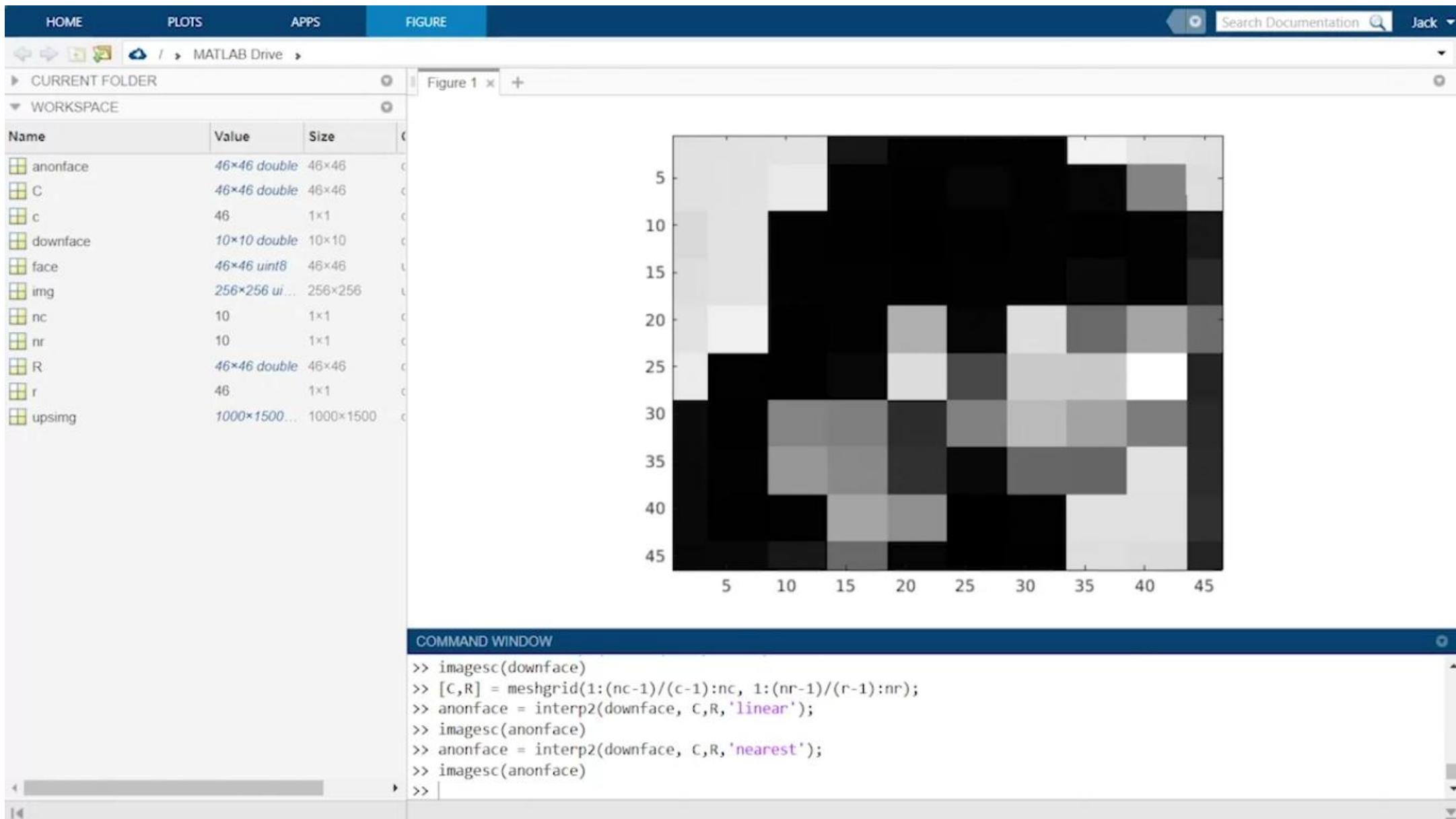


COMMAND WINDOW

```
>> nc = 1500;
>> [r,c] = size(img);
>> [C,R] = meshgrid(1:(c-1)/(nc-1):c, 1:(r-1)/(nr-1):r);
>> upsimg = interp2(double(img), C, R);
>> imagesc(upsimg)
>> colormap(gray)
```







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WORKSPACE

Name	Value	Size
anonface	46x46 double	46x46
C	46x46 double	46x46
c	46	1x1
downface	10x10 double	10x10
face	46x46 uint8	46x46
img	256x256 ui...	256x256
nc	10	1x1
nr	10	1x1
R	46x46 double	46x46
r	46	1x1
upsimg	1000x1500...	1000x1500

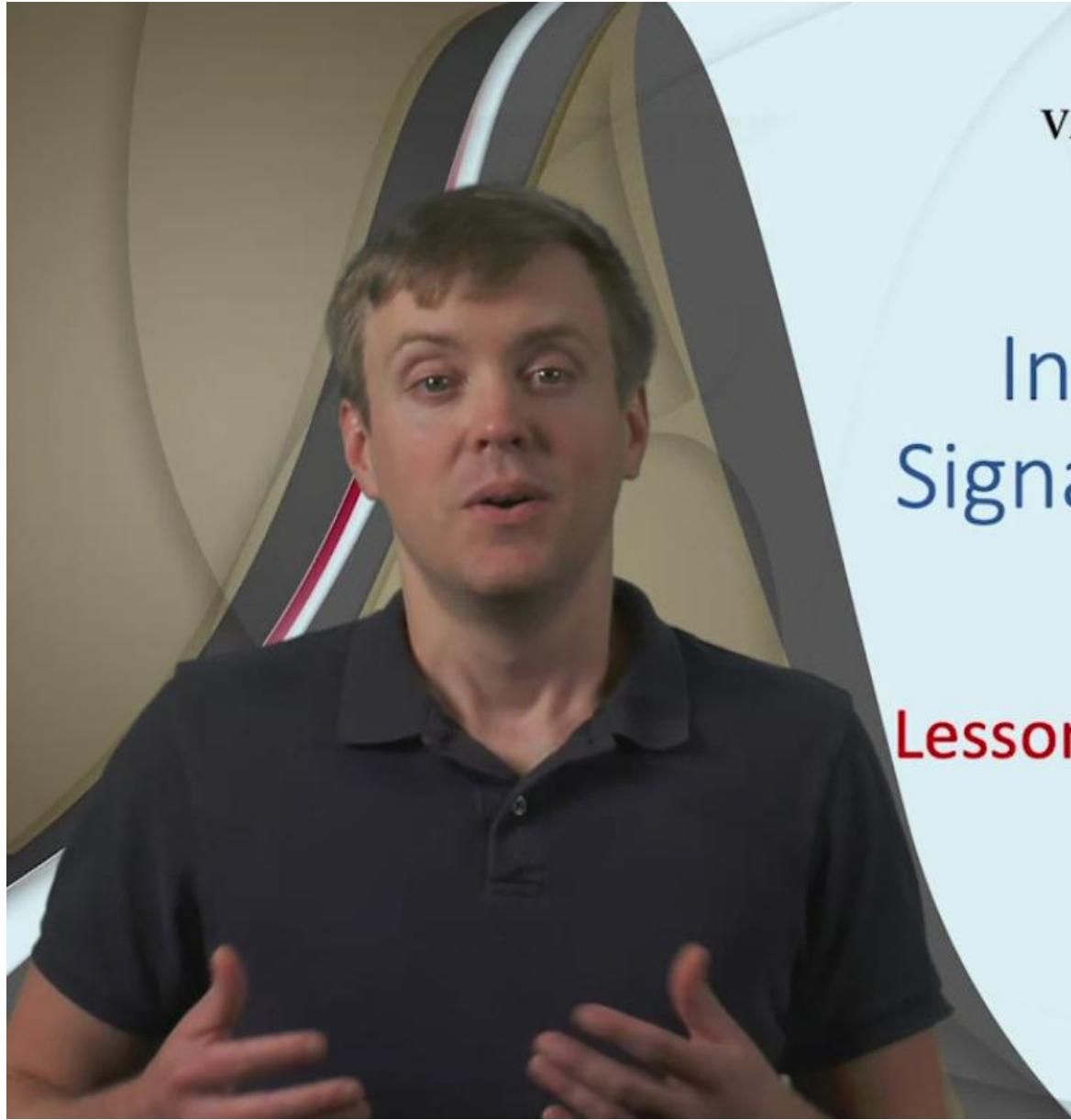
Figure 1



COMMAND WINDOW

```
>> anonface = interp2(downface, C,R,'linear');
>> imagesc(anonface)
>> anonface = interp2(downface, C,R,'nearest');
>> imagesc(anonface)
>> img(40:85, 90:135) = anonface;
>> imagesc(img)
```

>>



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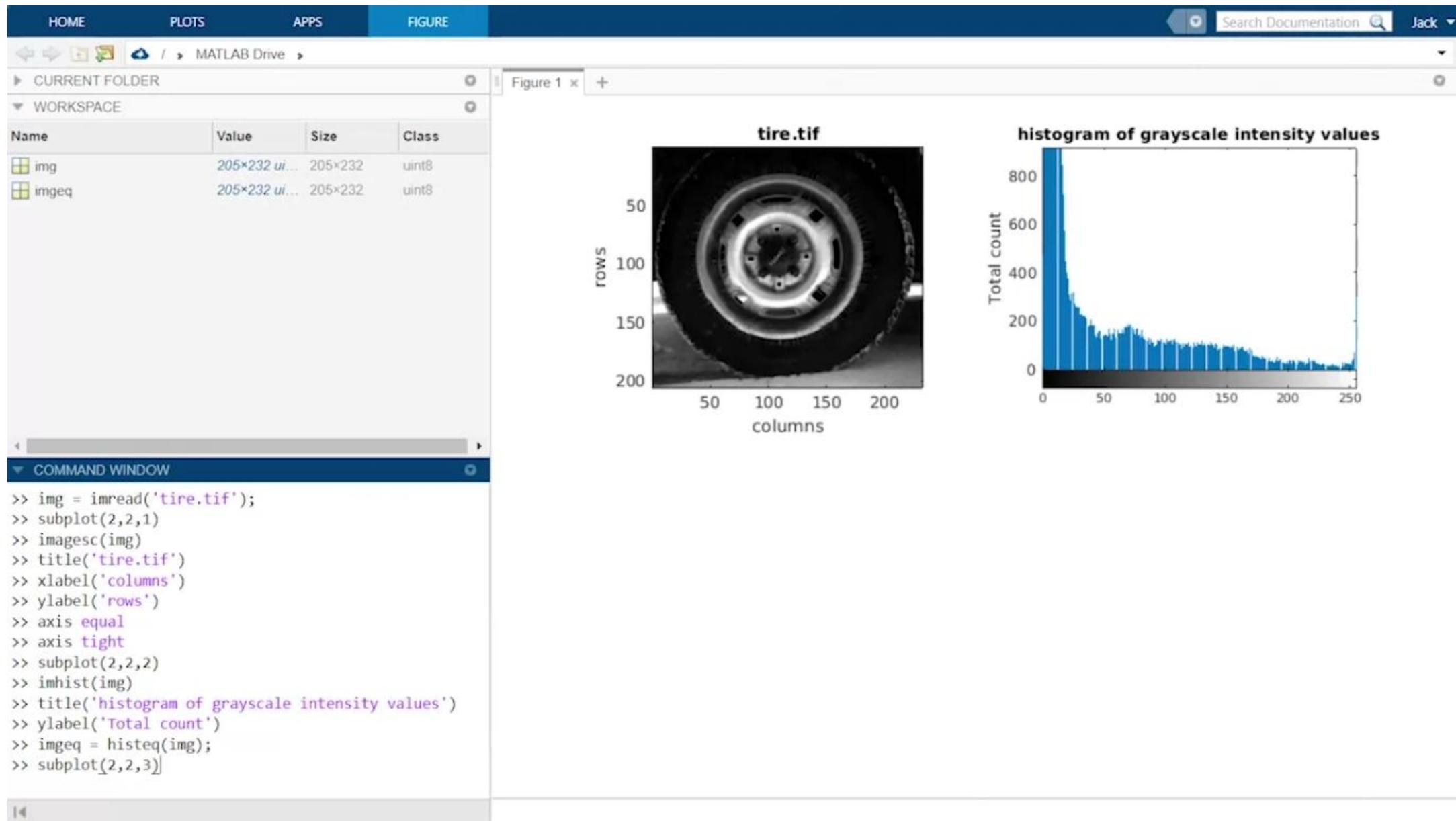
00:11 / 32:57
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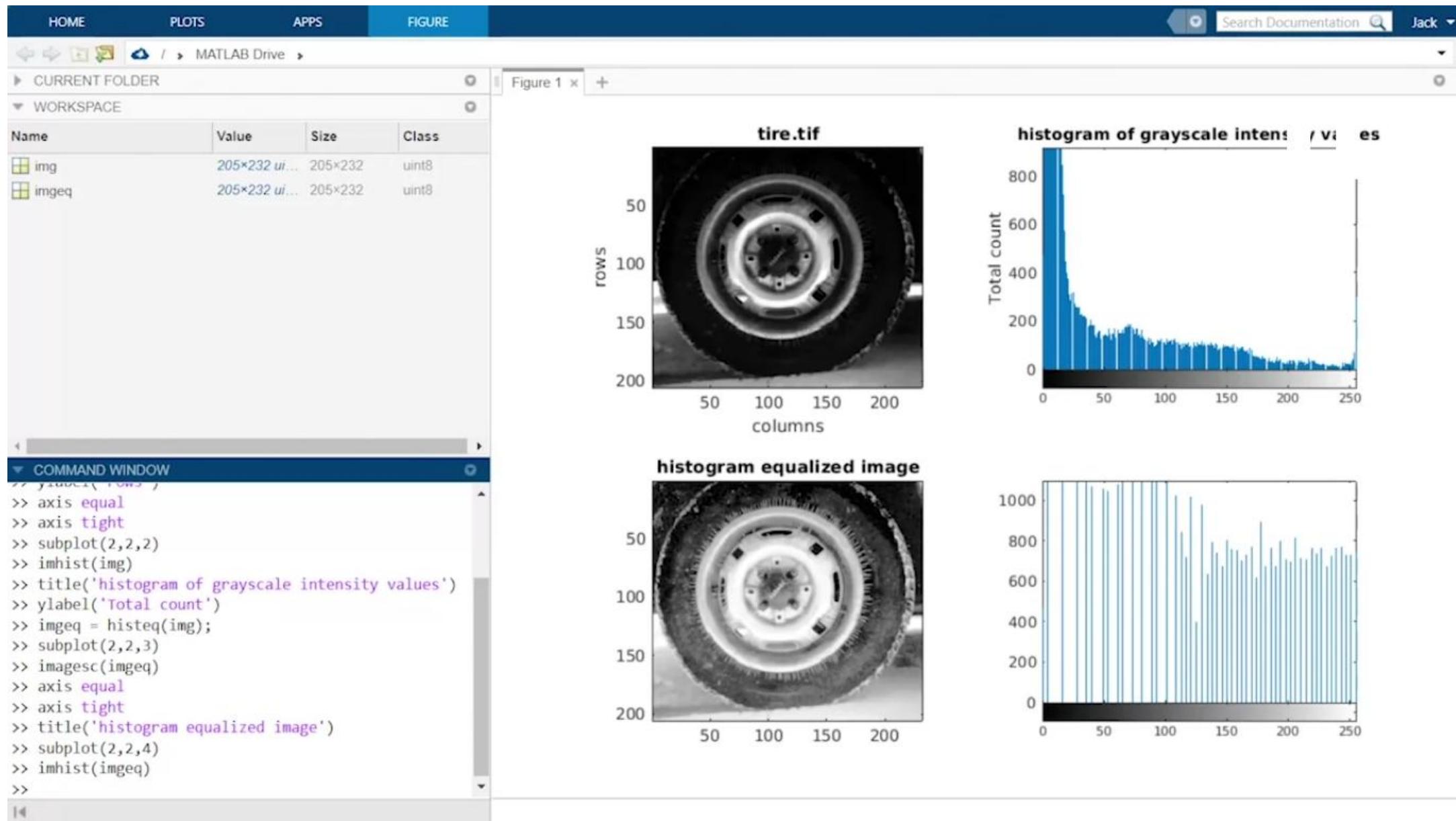
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Lesson 4.3 Image Intensity & Color Distributions

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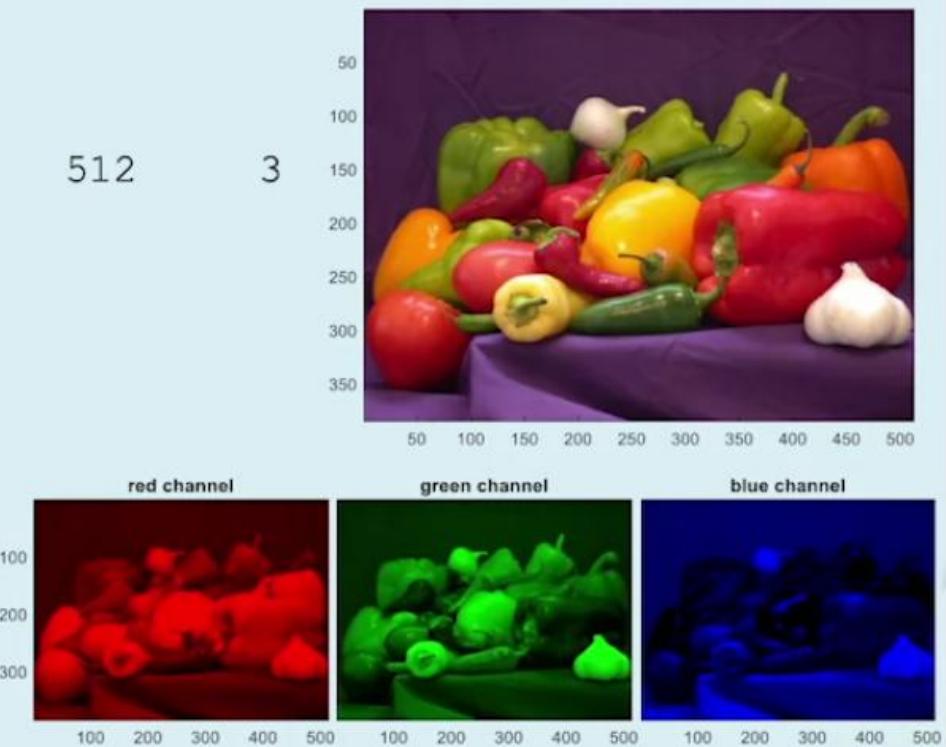




```
>> img = imread('peppers.png');  
>> size(img)
```

ans =

384 512 3

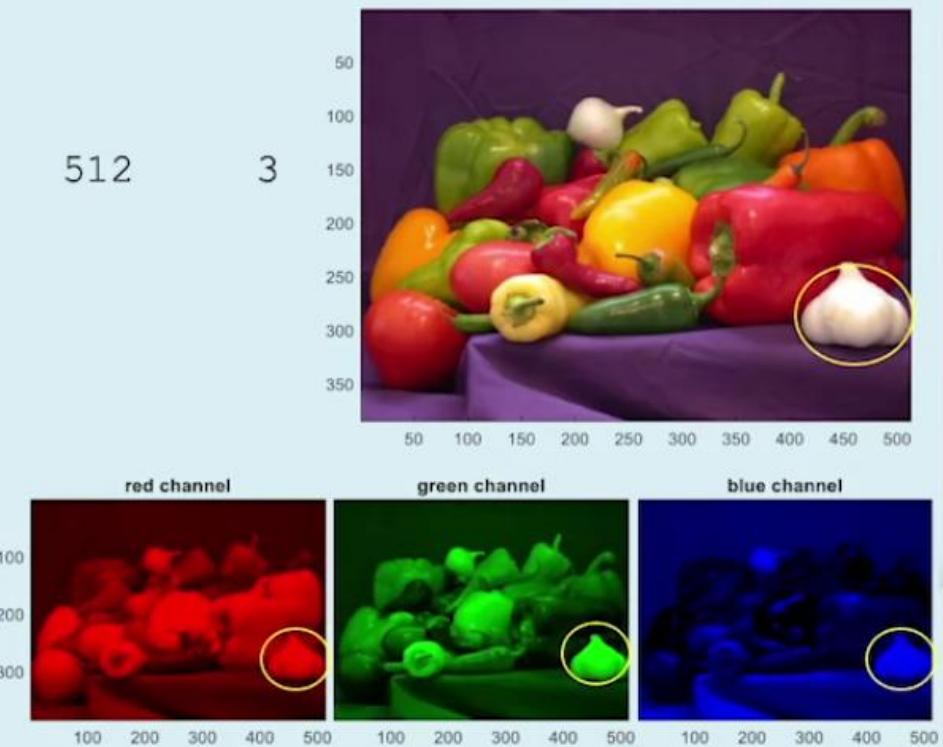


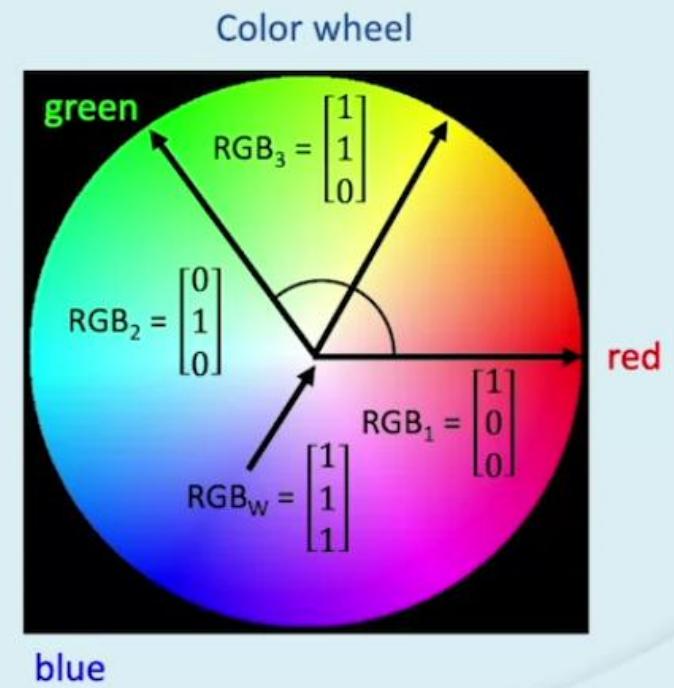
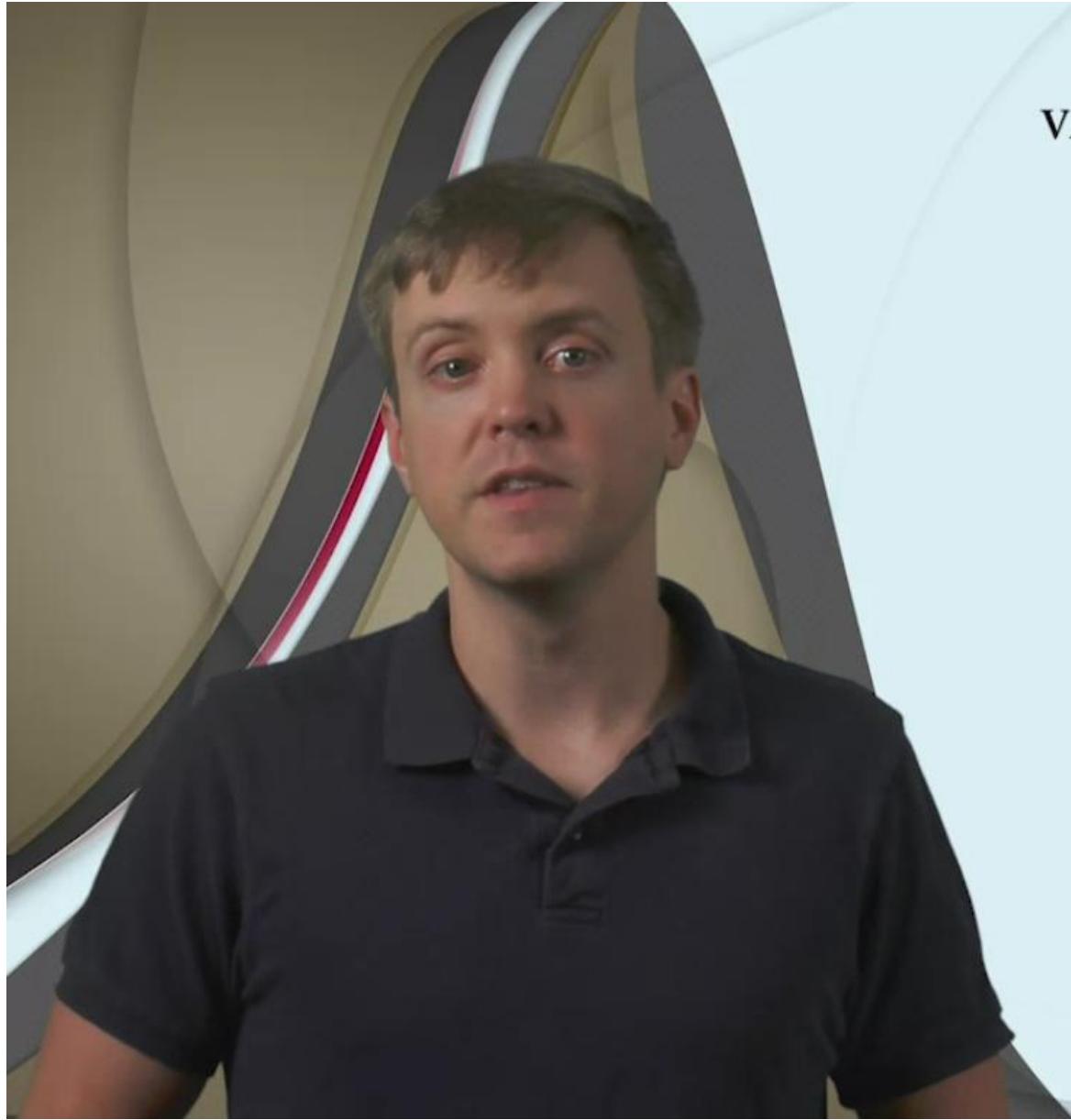


```
>> img = imread('peppers.png');  
>> size(img)
```

ans =

384 512 3

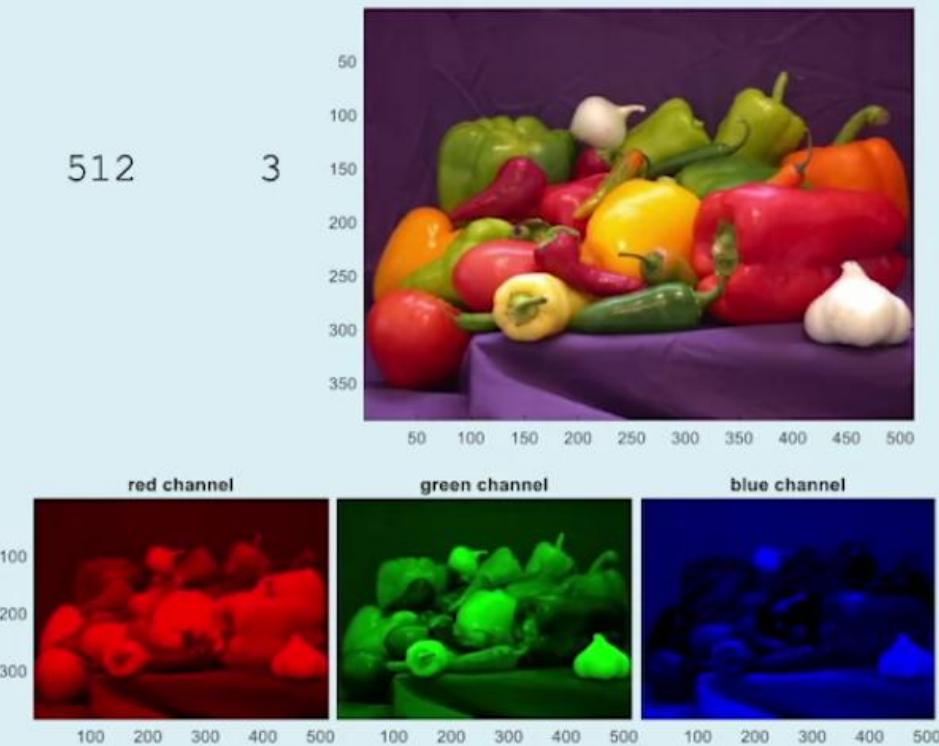


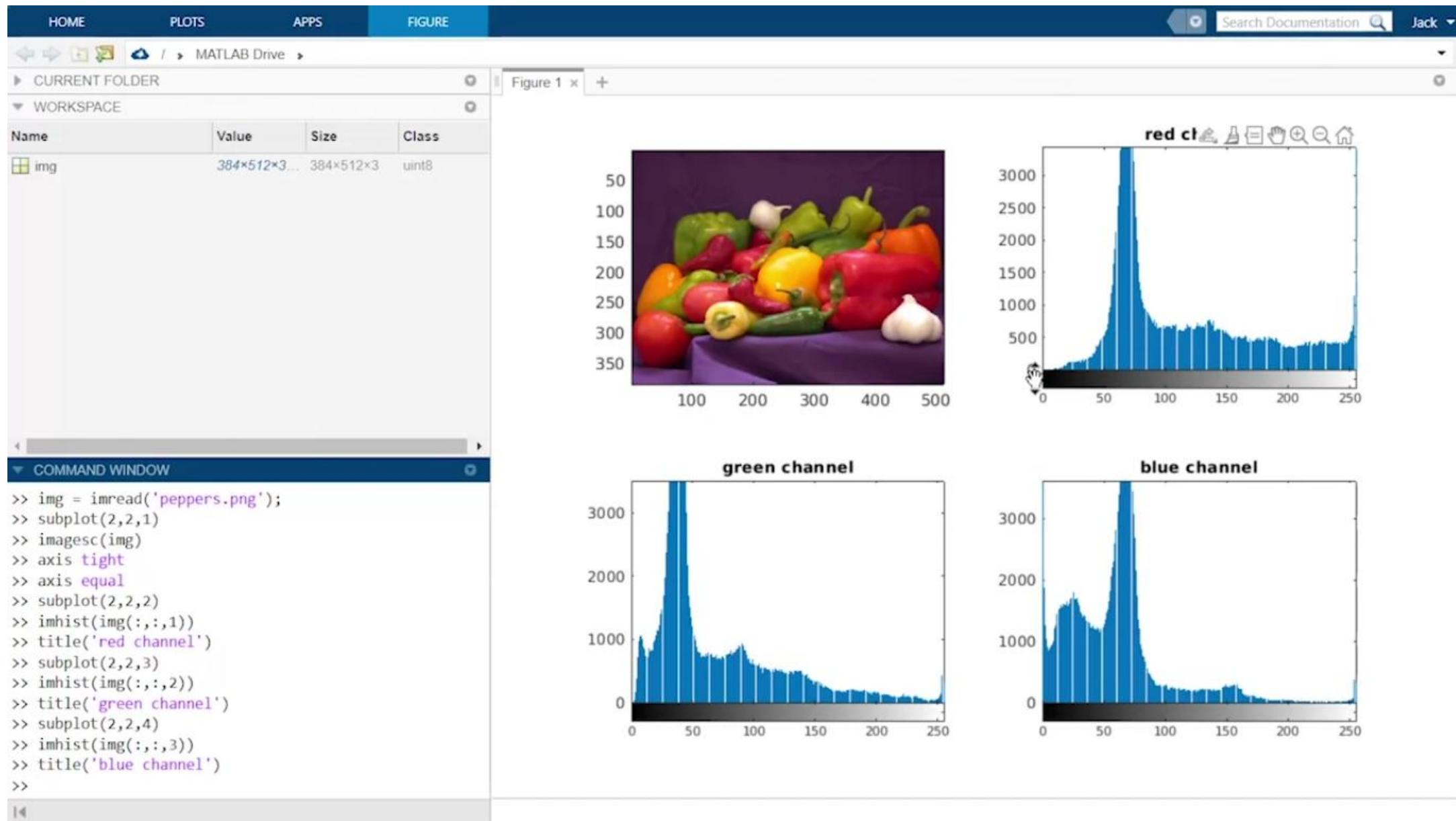


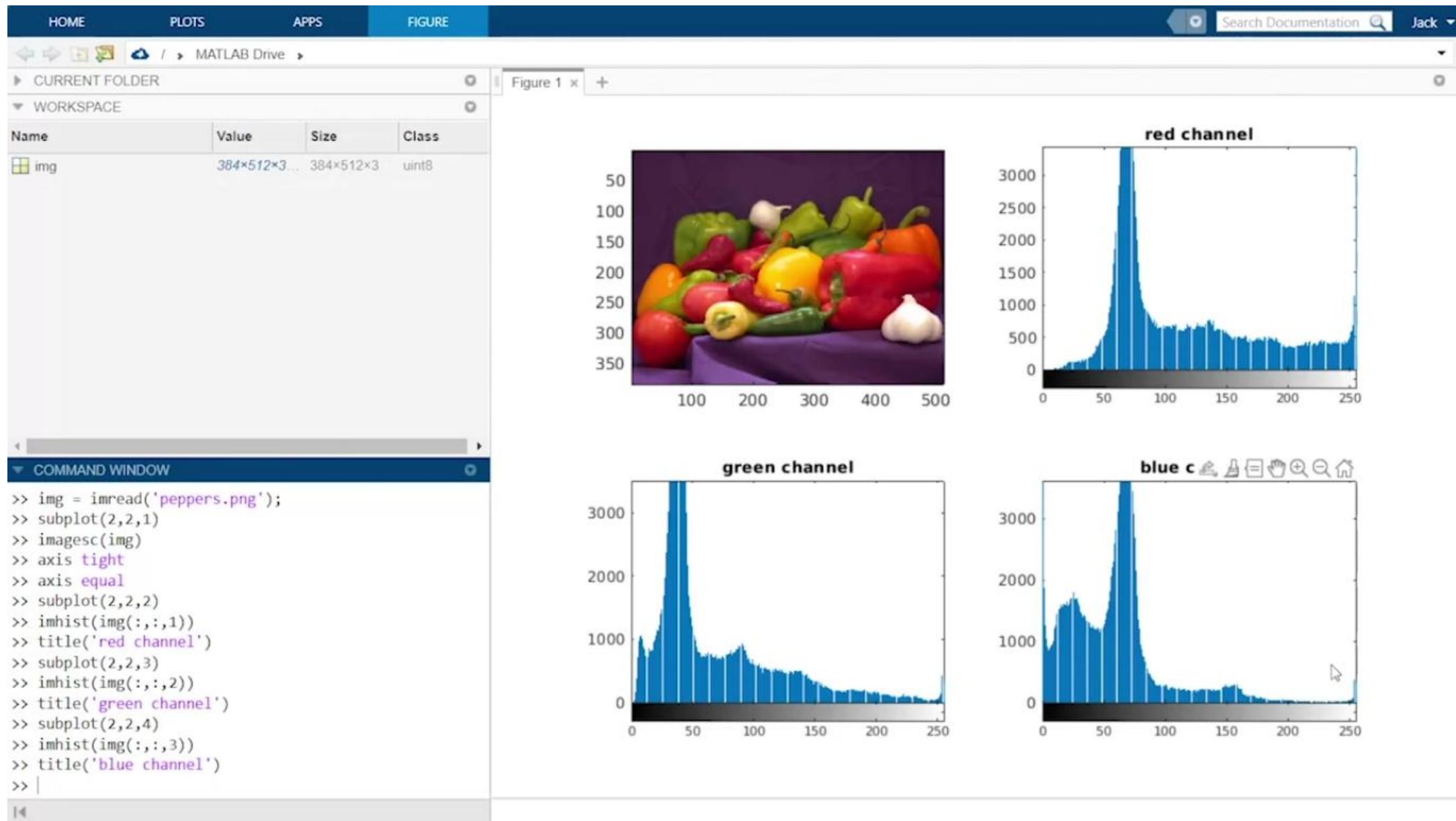
```
>> img = imread('peppers.png');  
>> size(img)
```

```
ans =
```

```
384 512 3
```

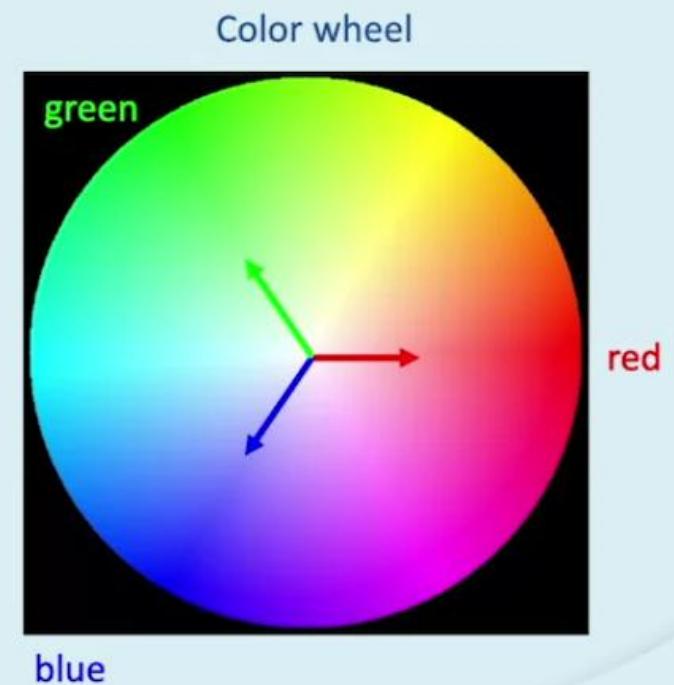
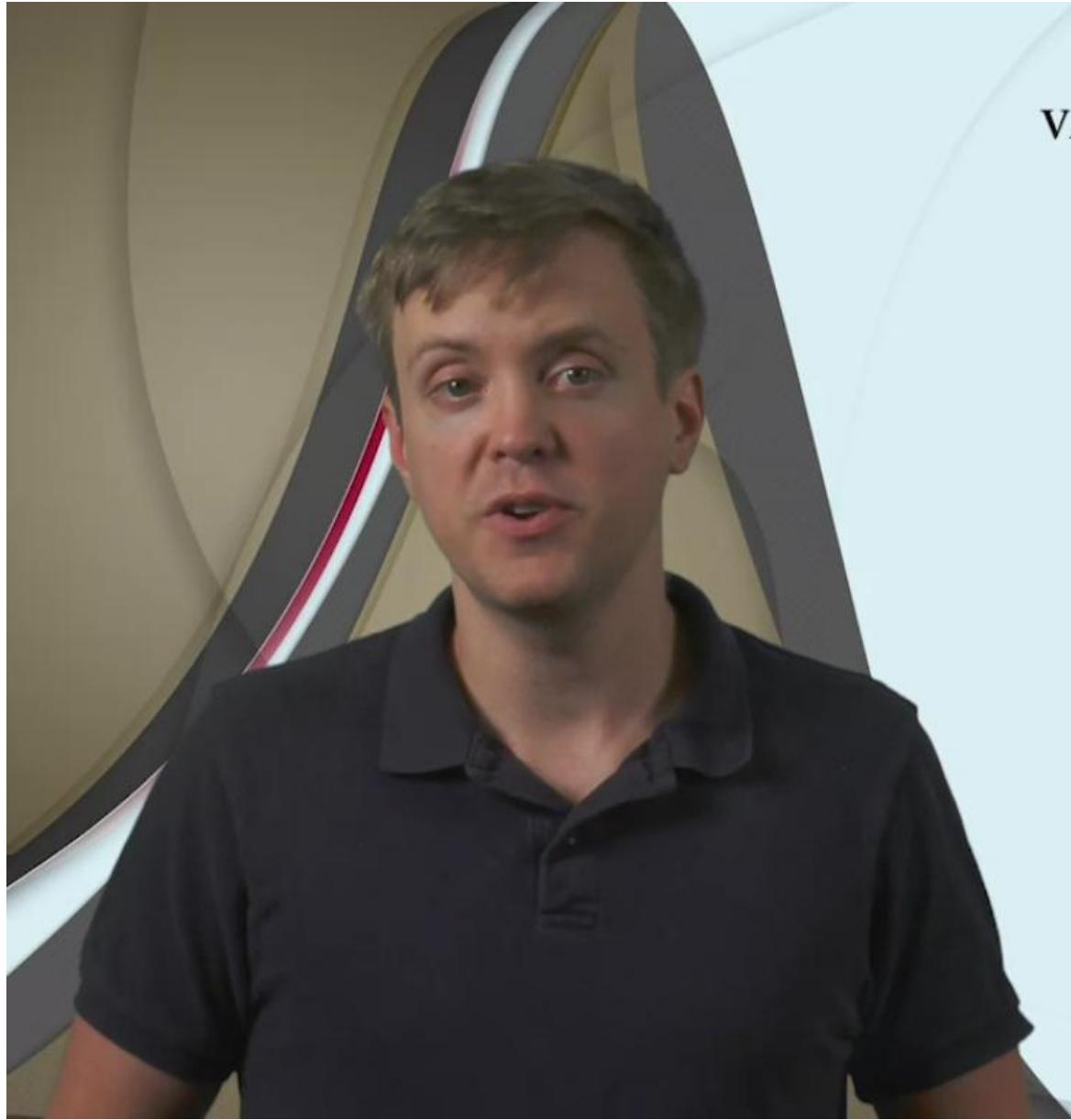


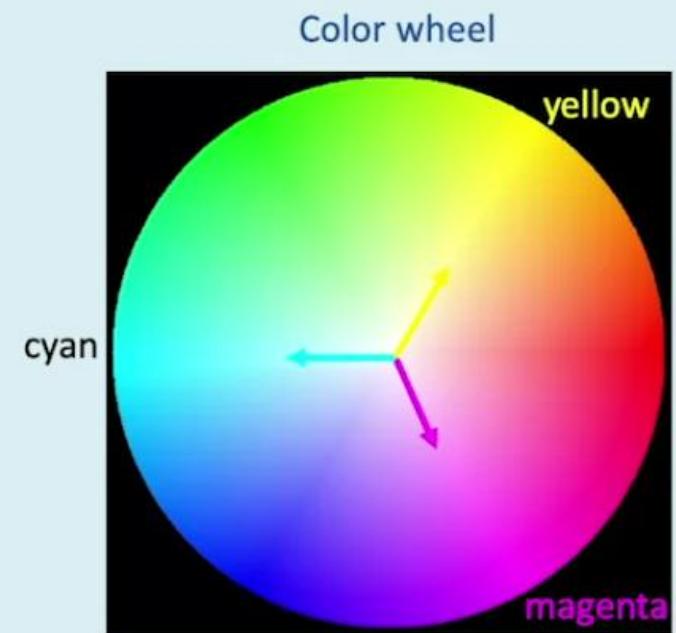


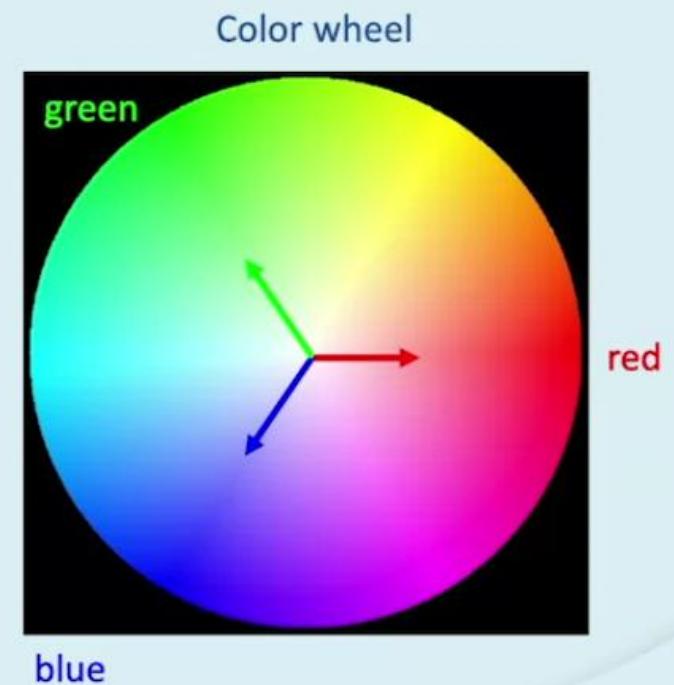


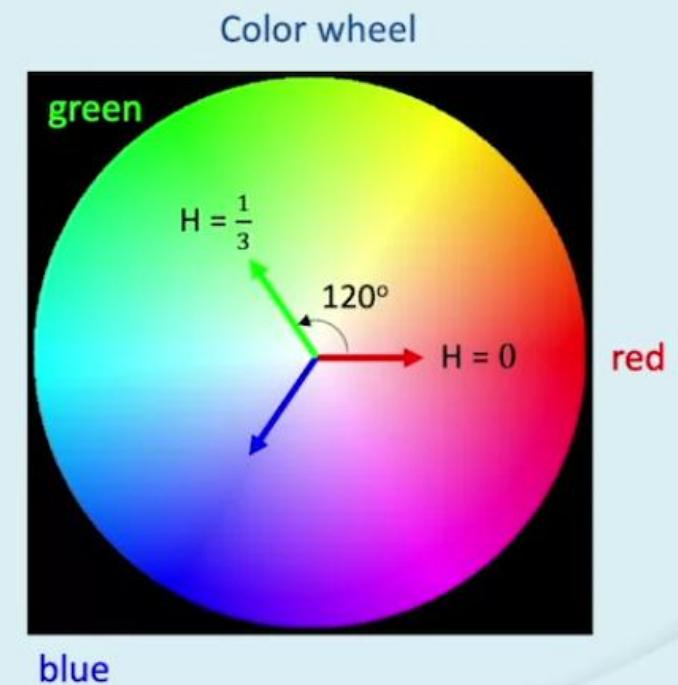
COMMAND WINDOW

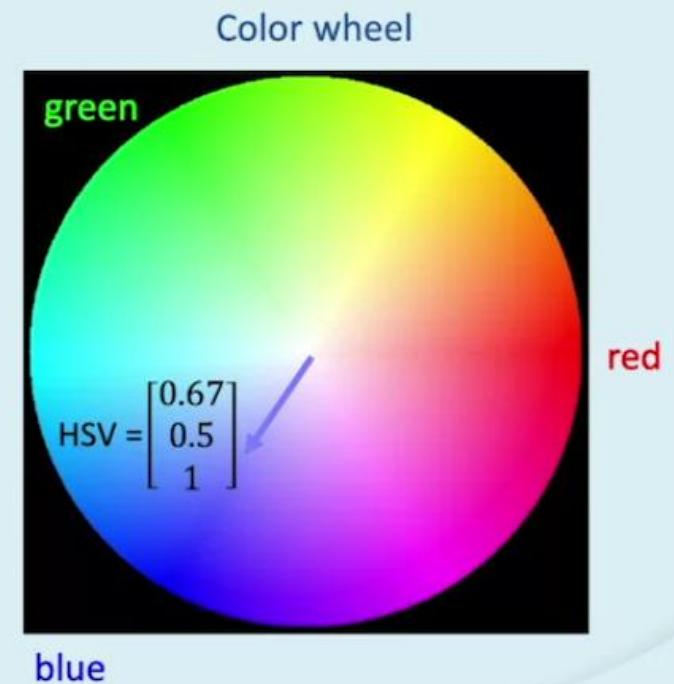
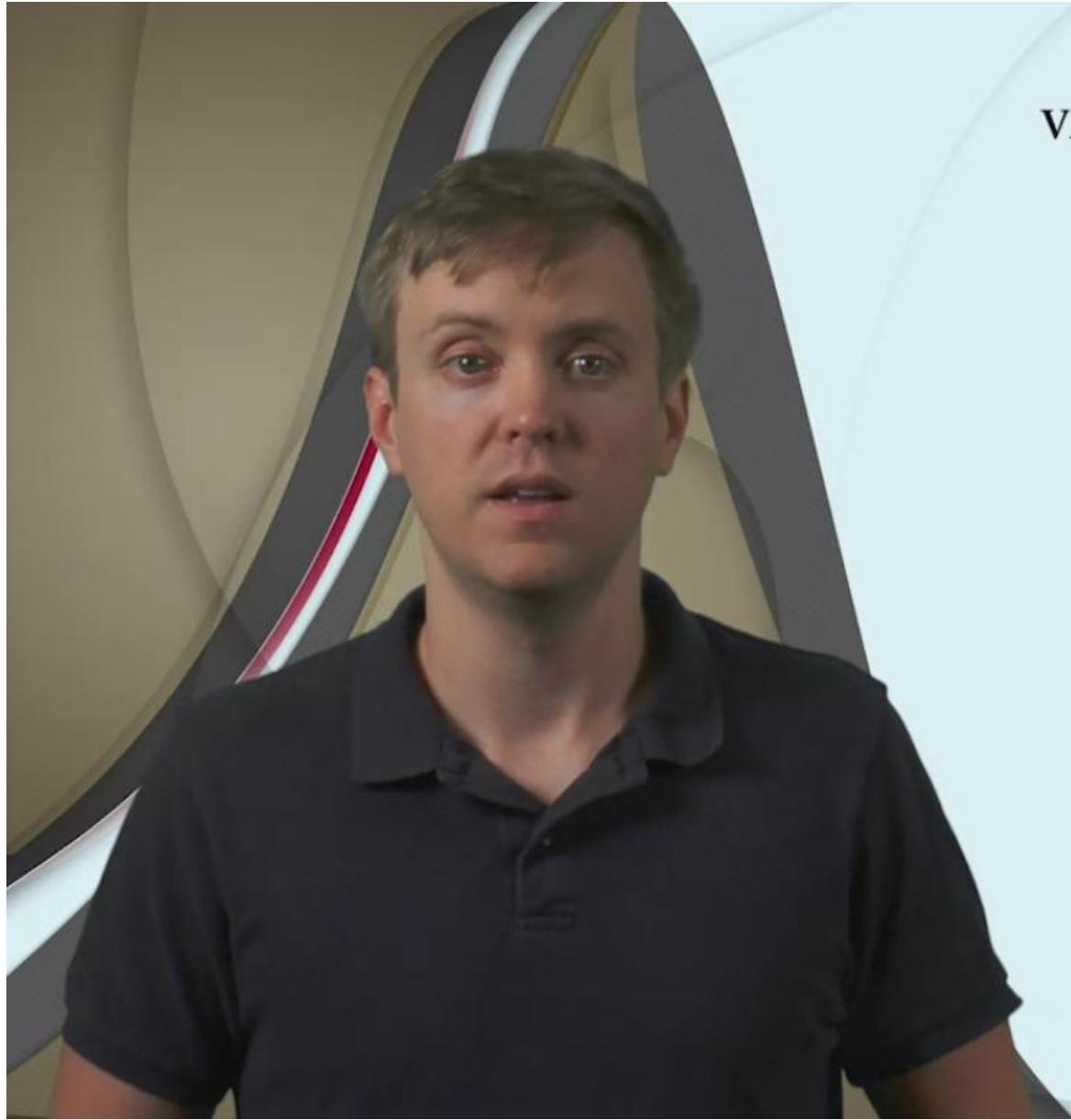
```
>> img = imread('peppers.png');
>> subplot(2,2,1)
>> imagesc(img)
>> axis tight
>> axis equal
>> subplot(2,2,2)
>> imhist(img(:,:,1))
>> title('red channel')
>> subplot(2,2,3)
>> imhist(img(:,:,2))
>> title('green channel')
>> subplot(2,2,4)
>> imhist(img(:,:,3))
>> title('blue channel')
>> |
```



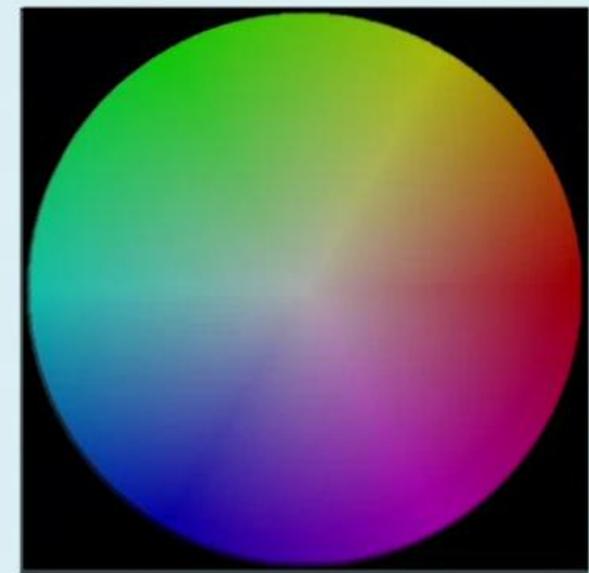


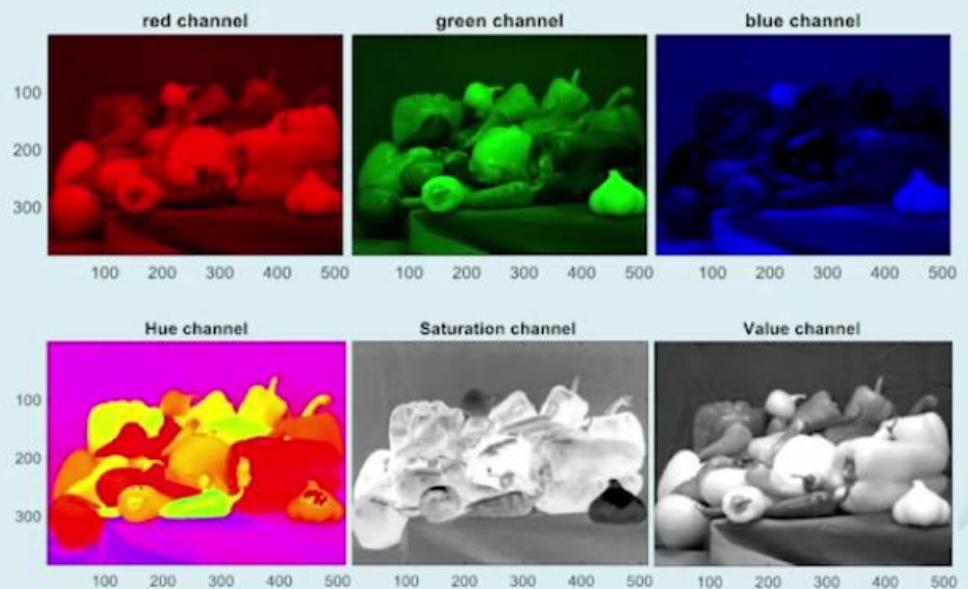


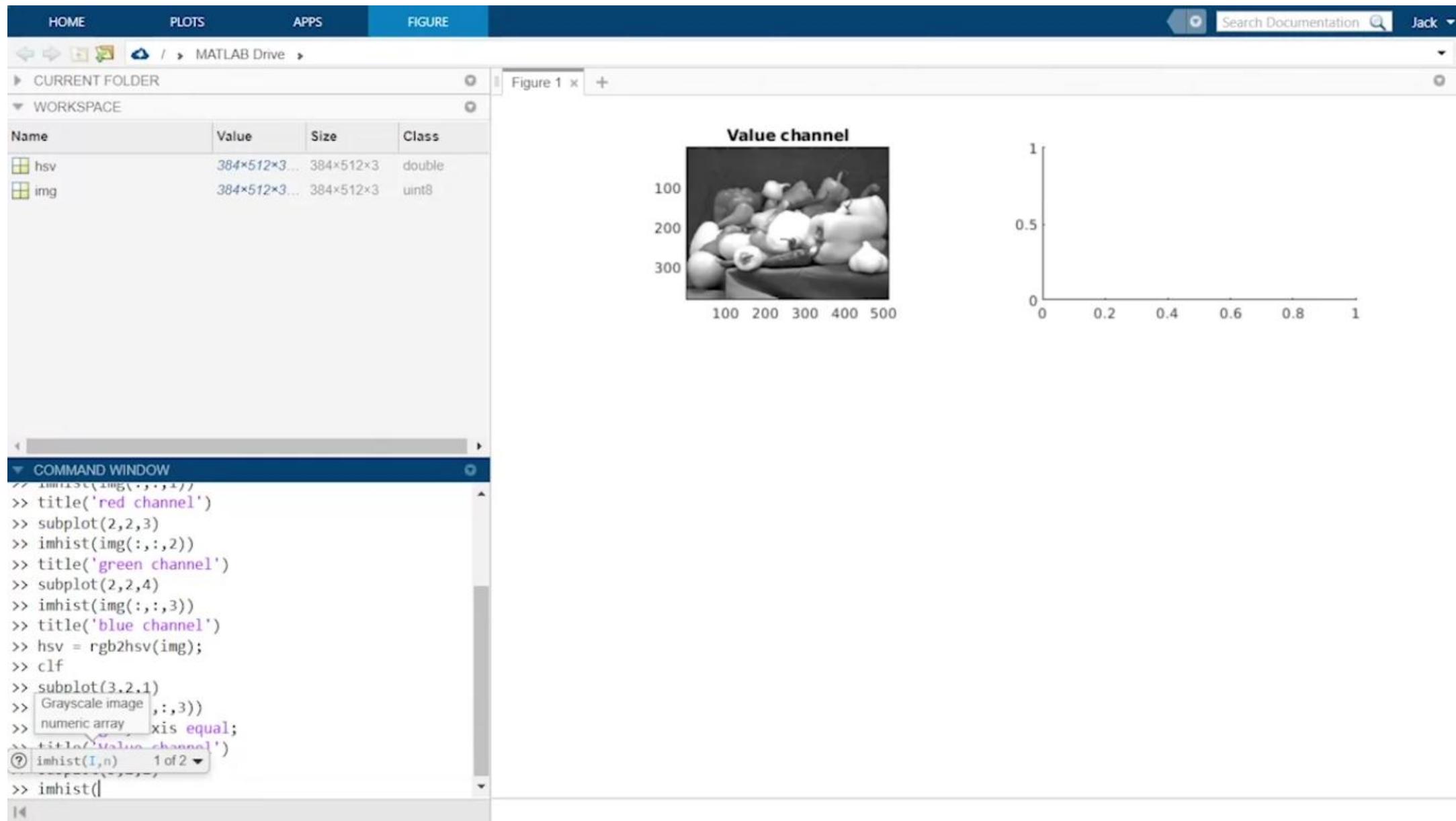


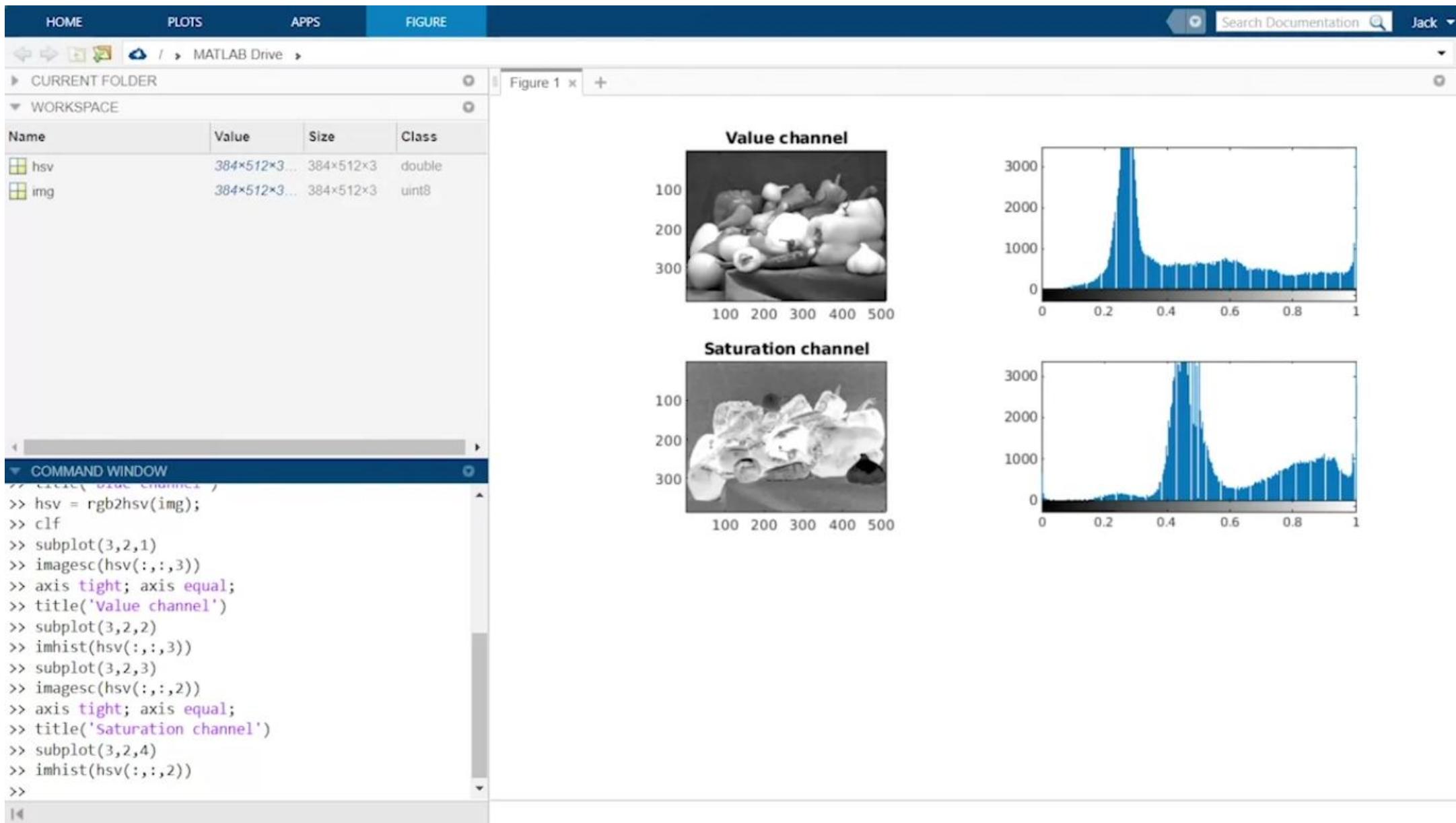


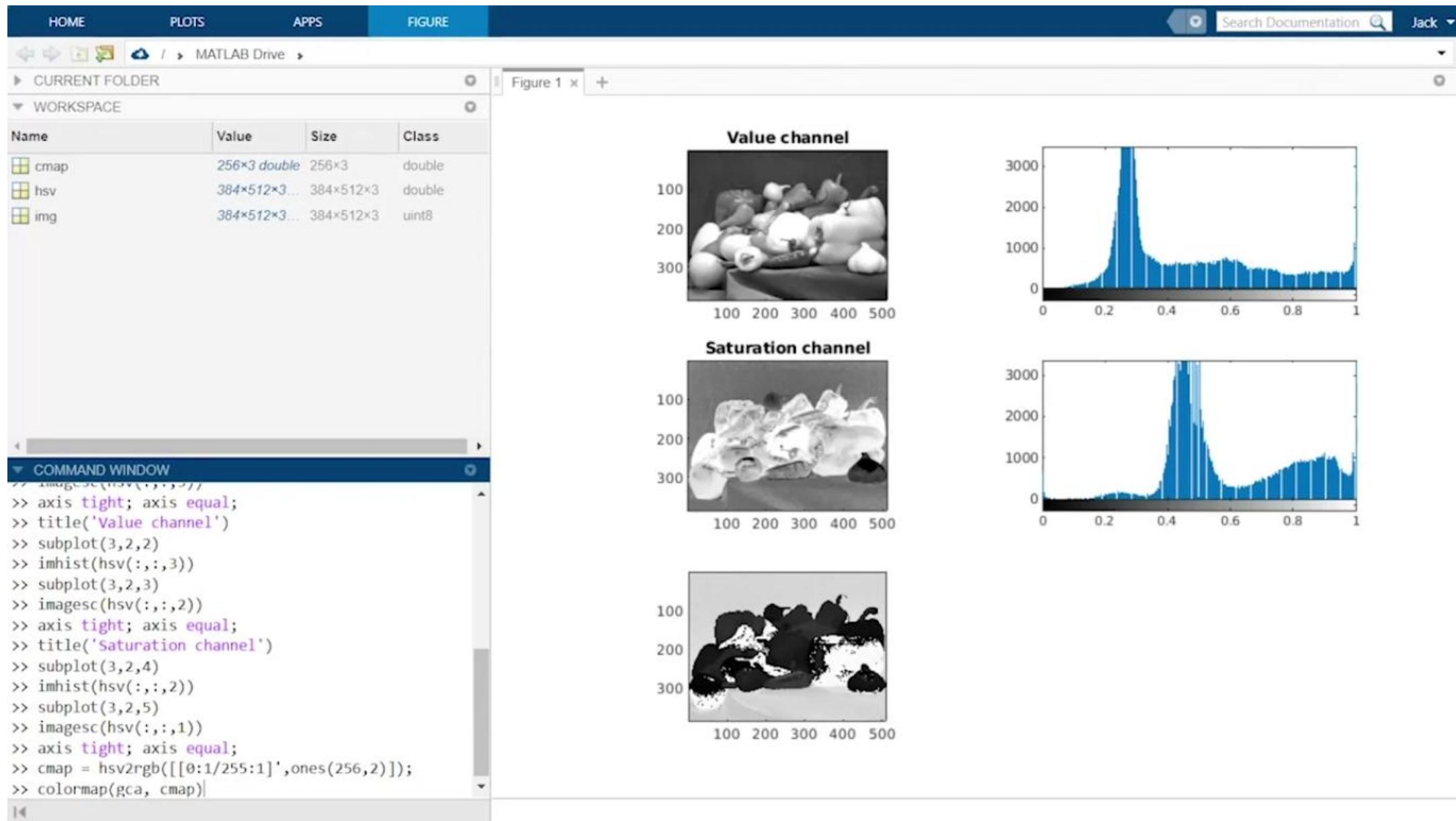
Color wheel (Value=0.15)

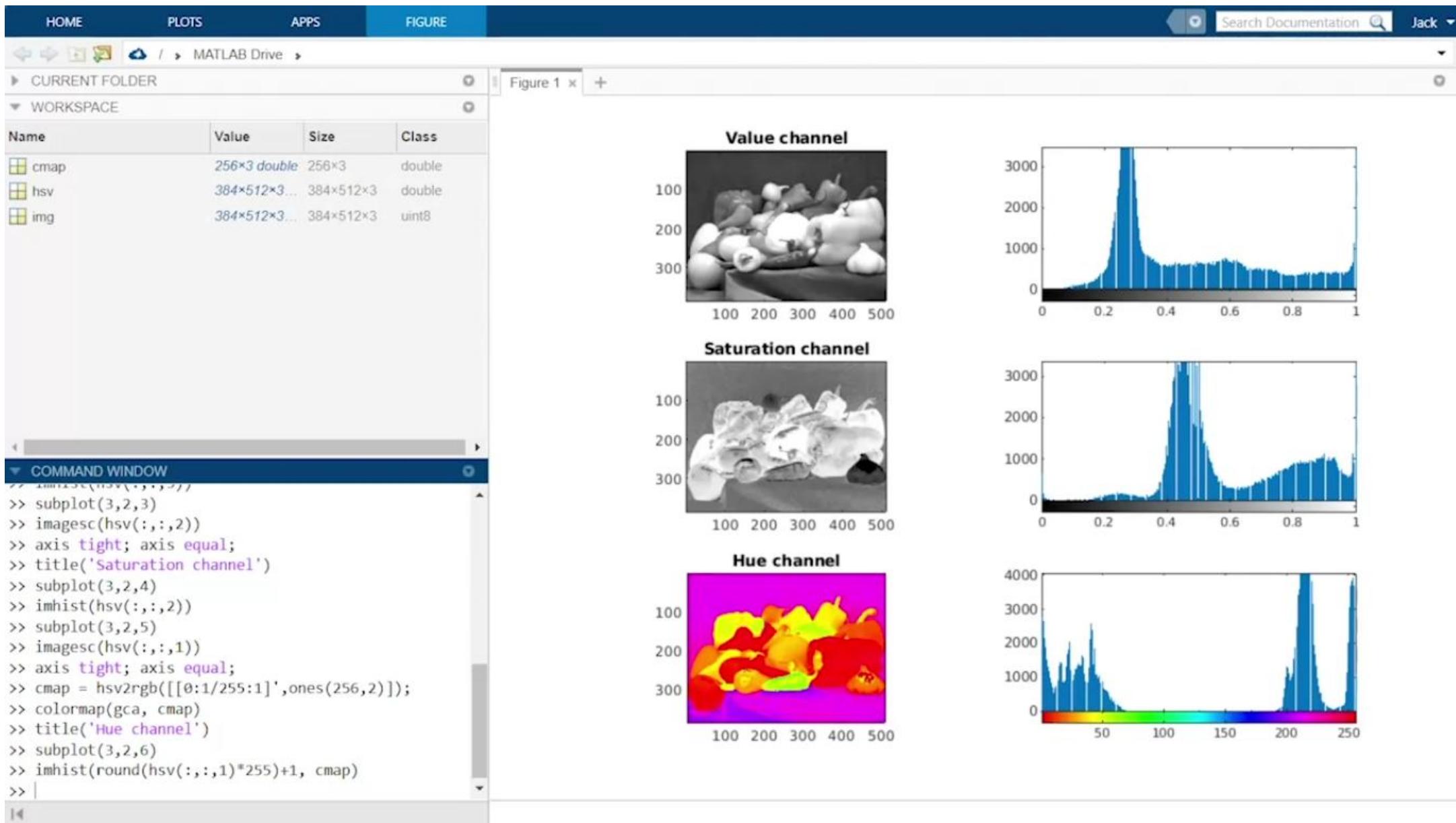


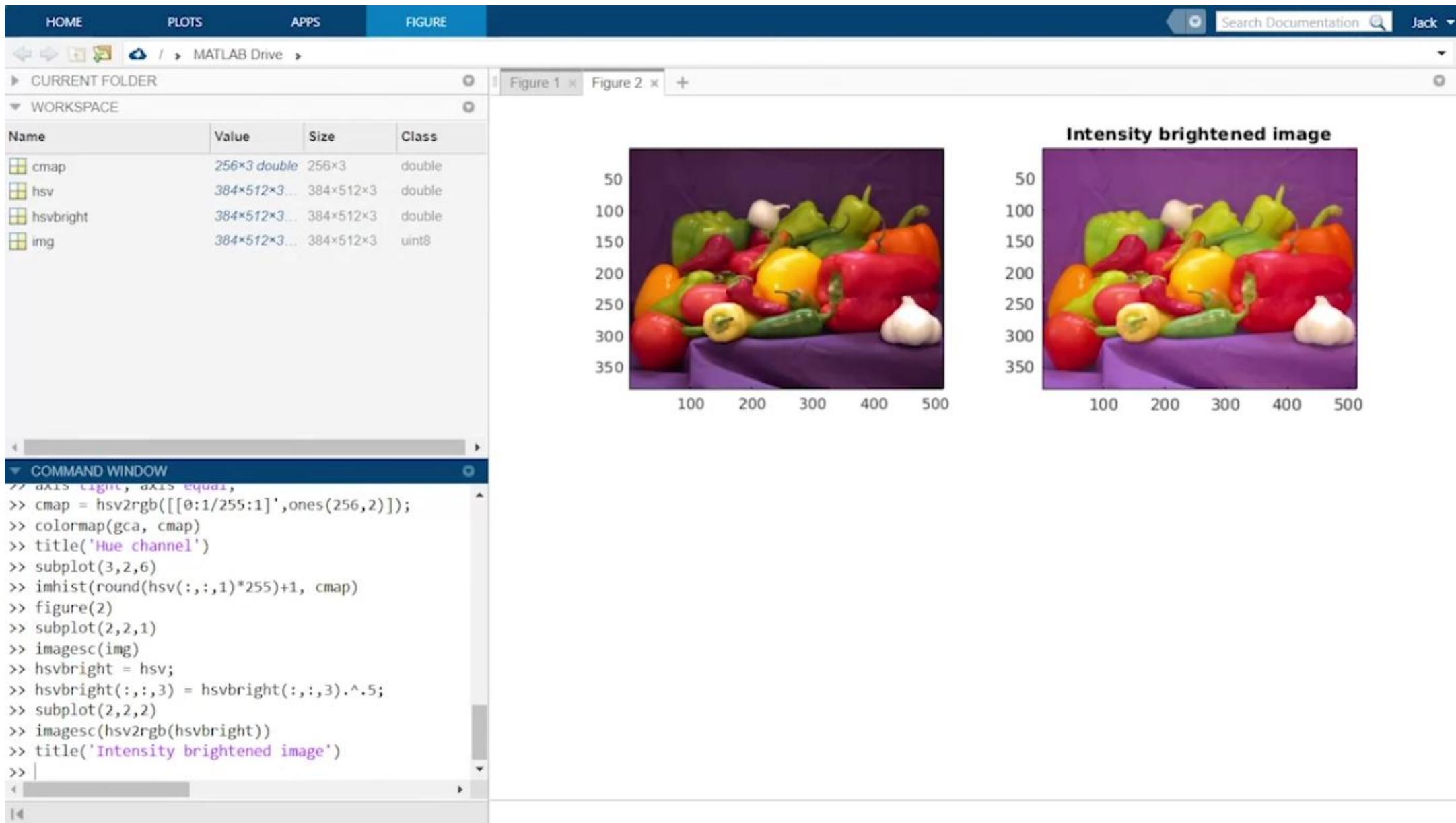


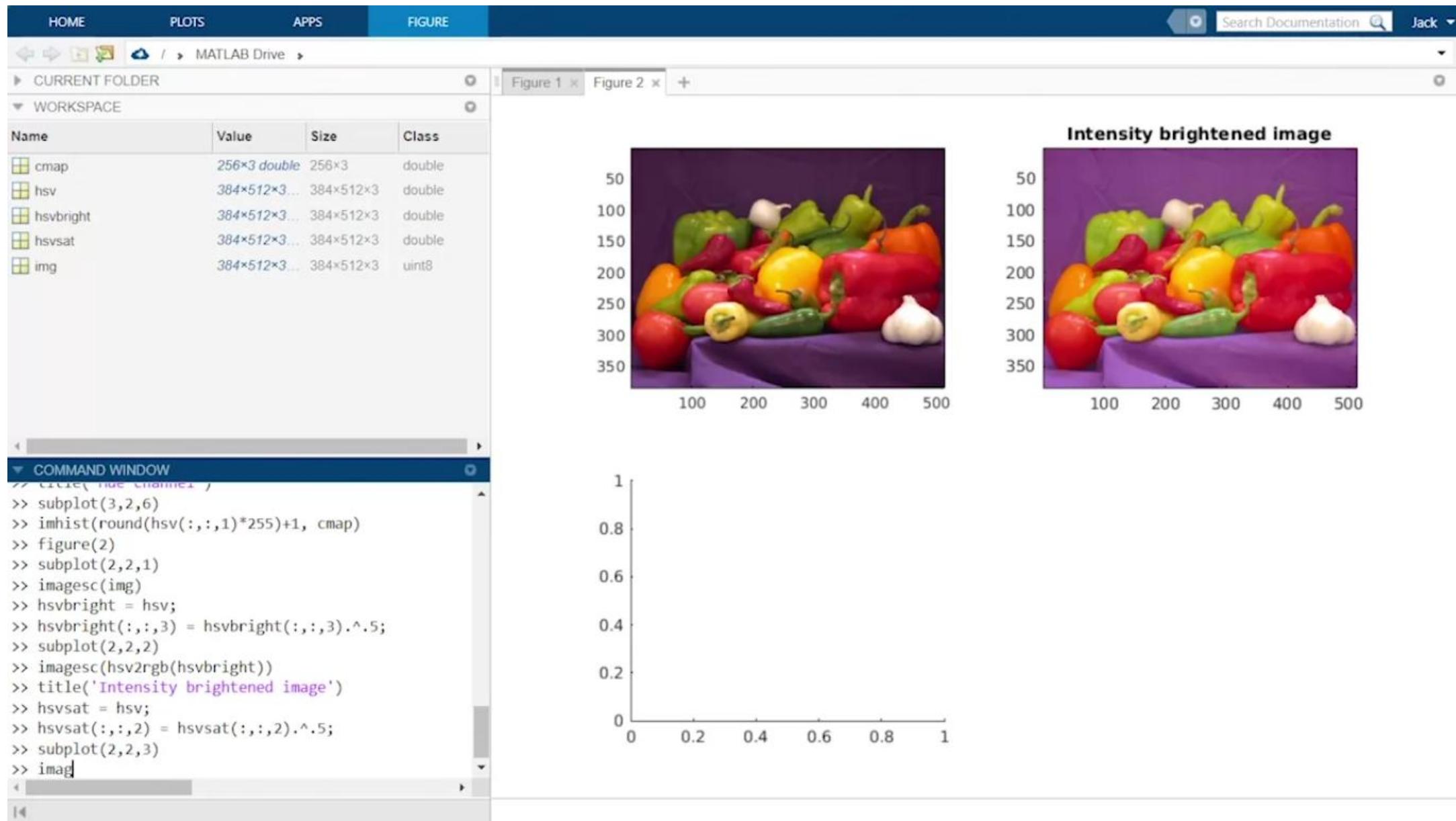


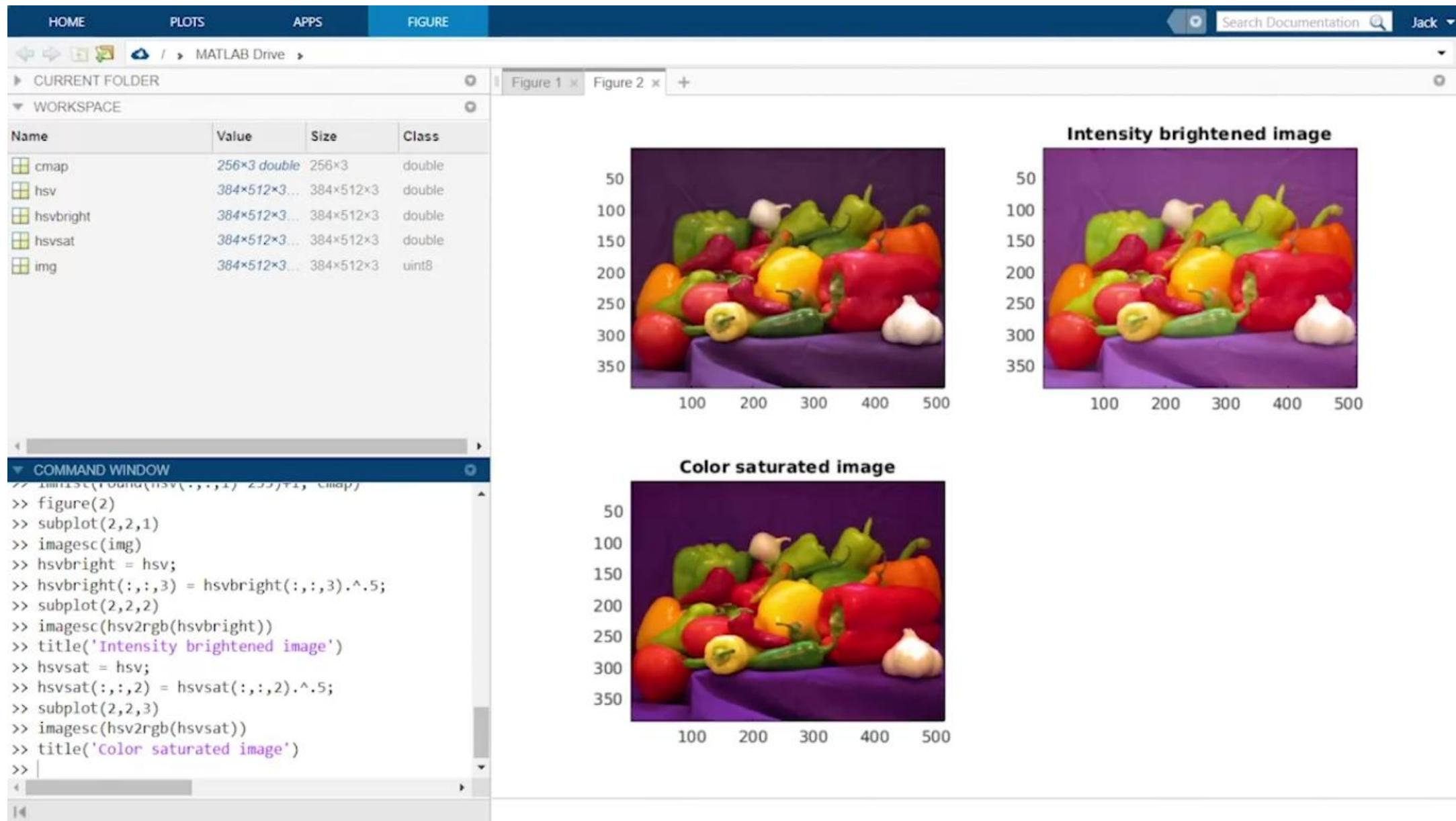


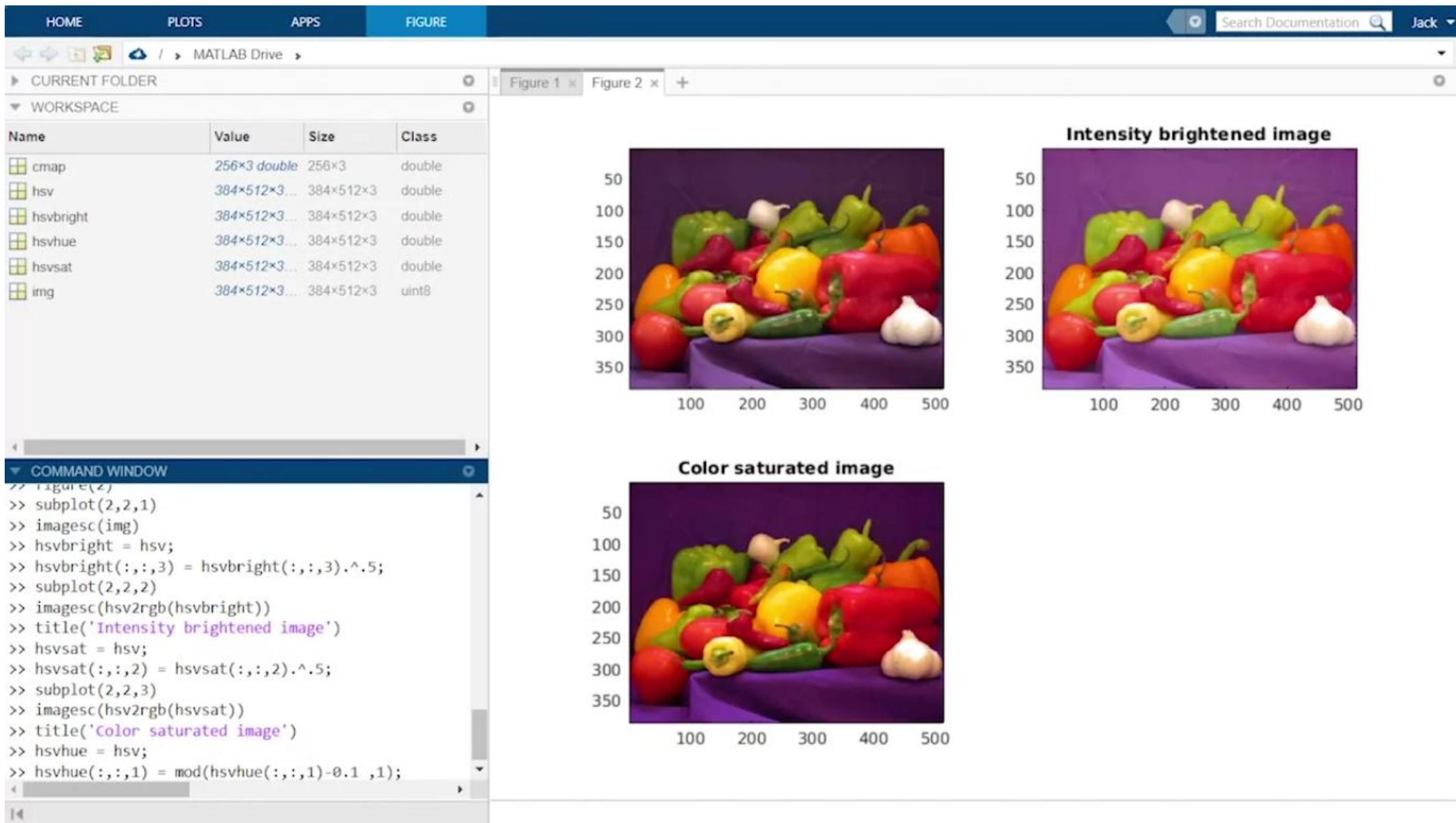


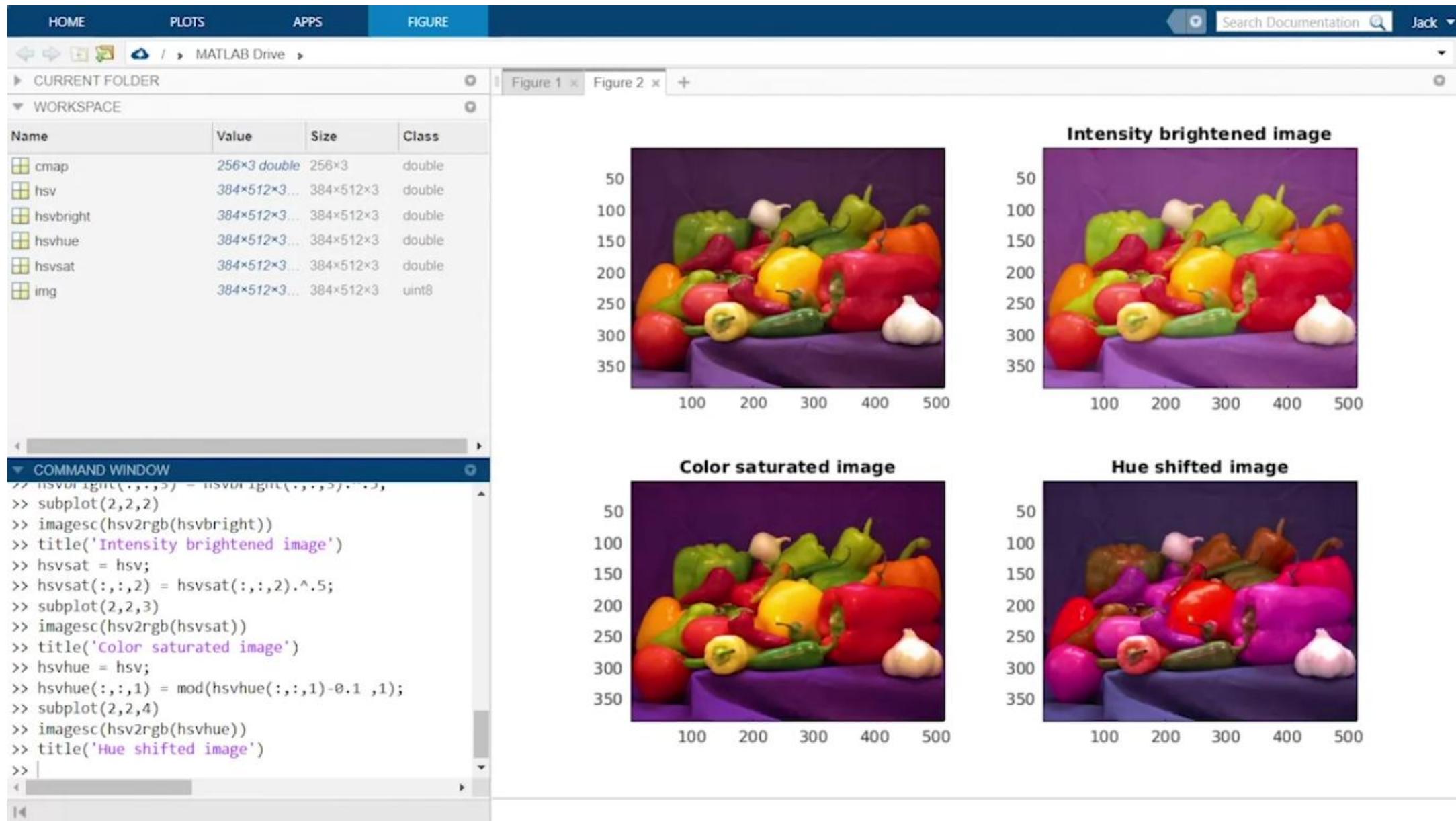


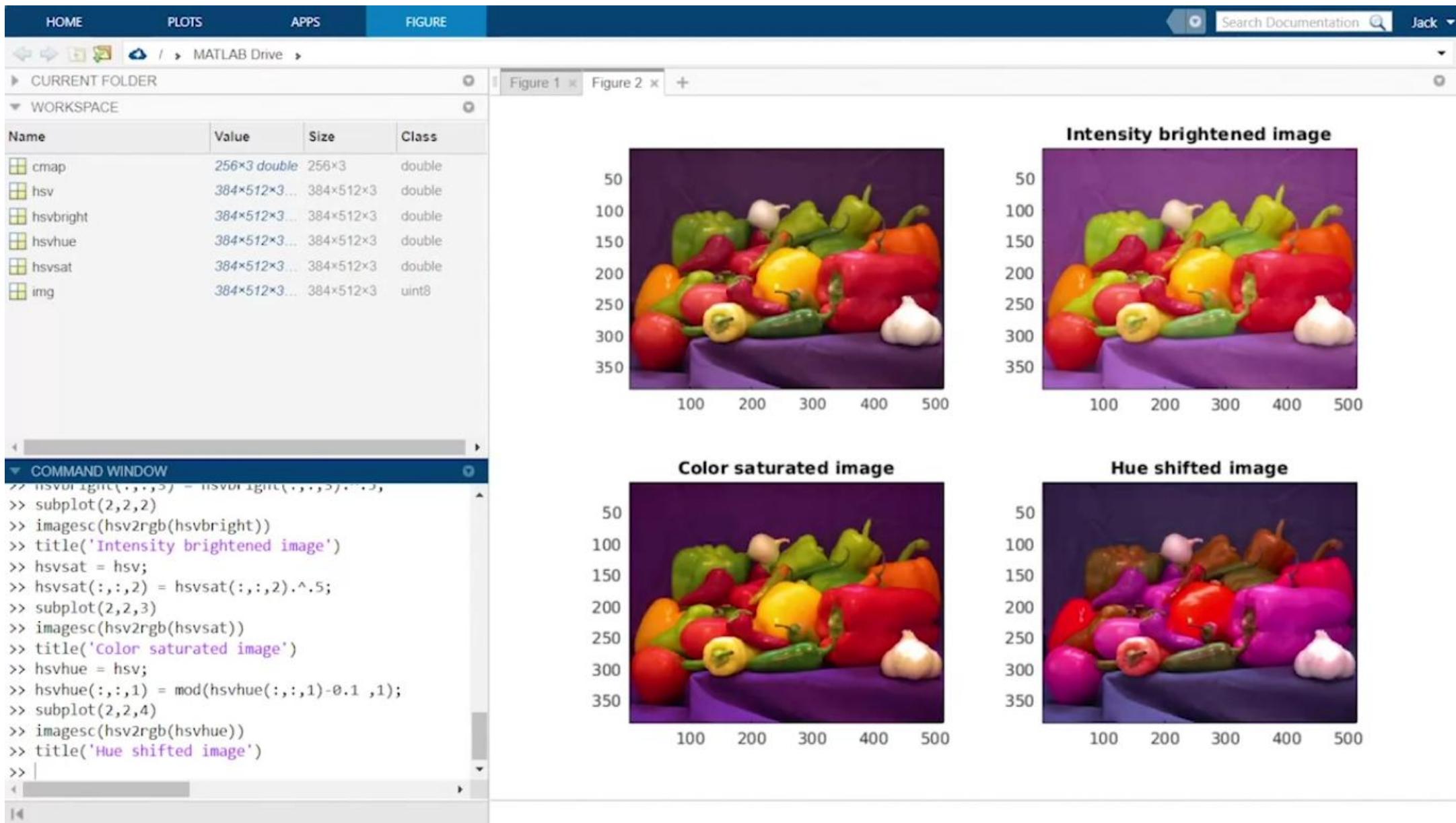












00:13 / 58:23

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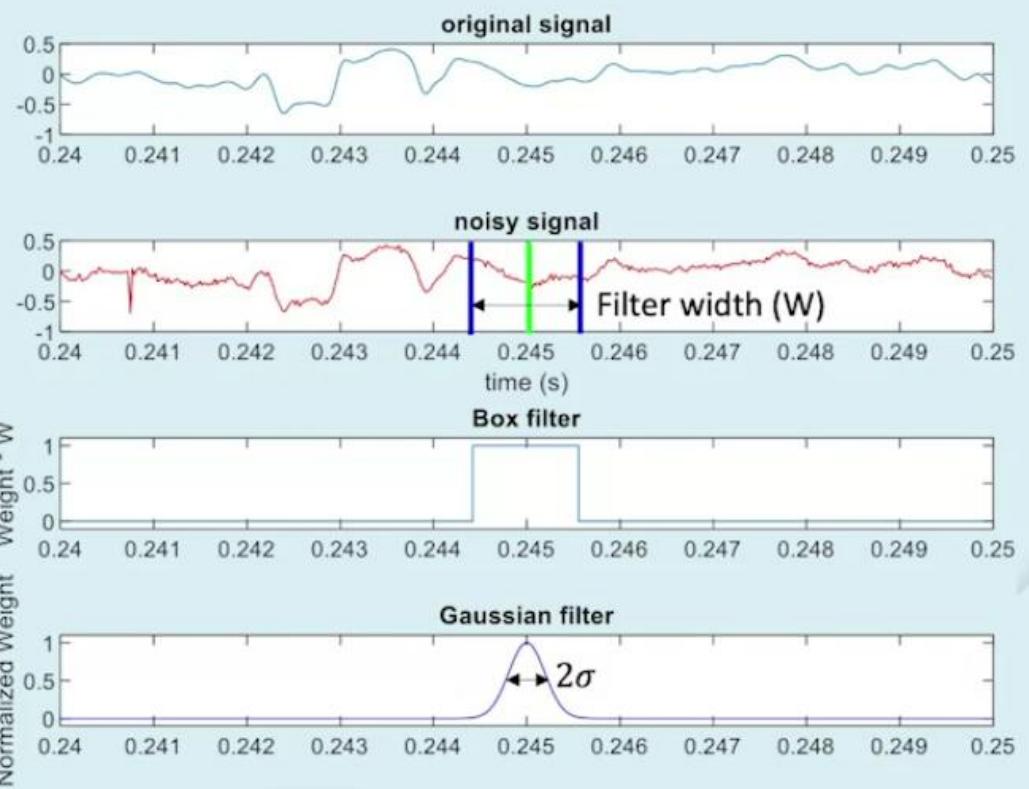
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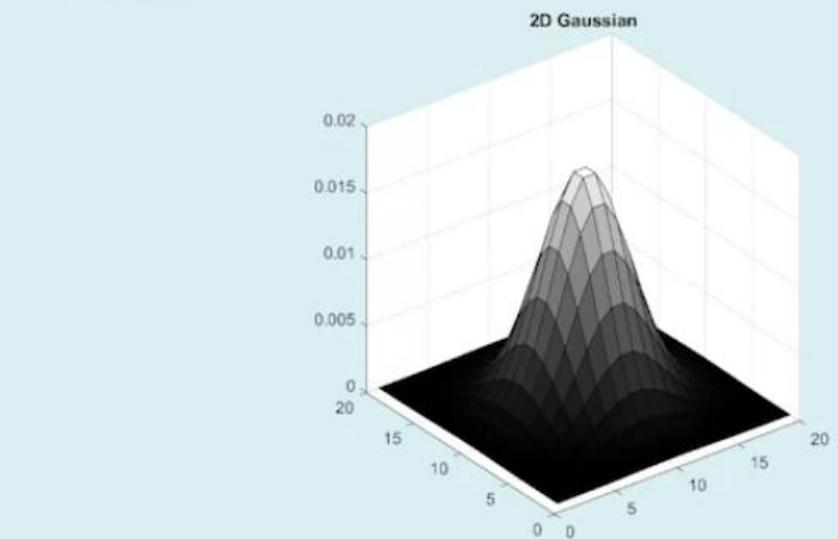
Lesson 4.4 Image Filtering

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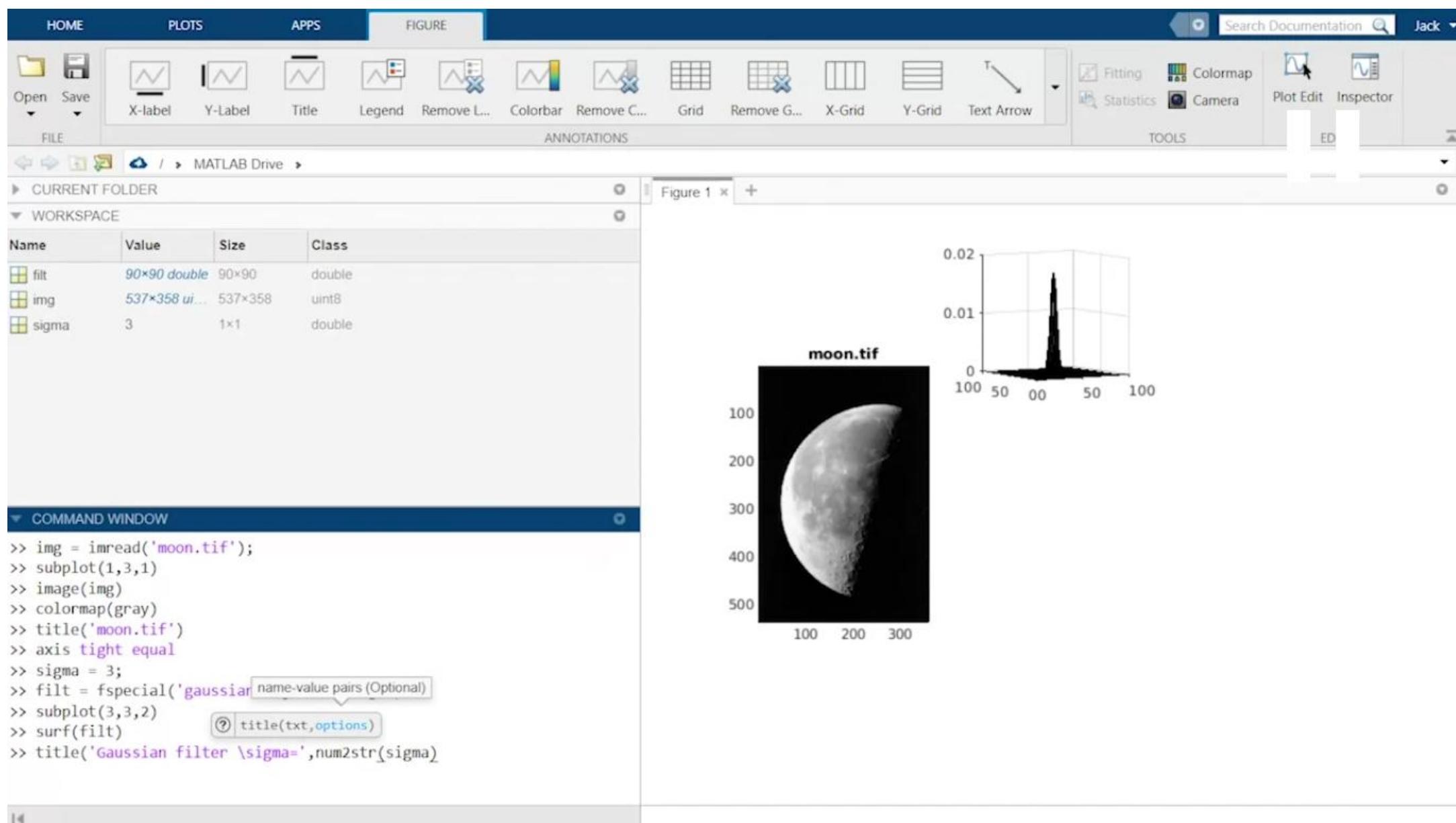
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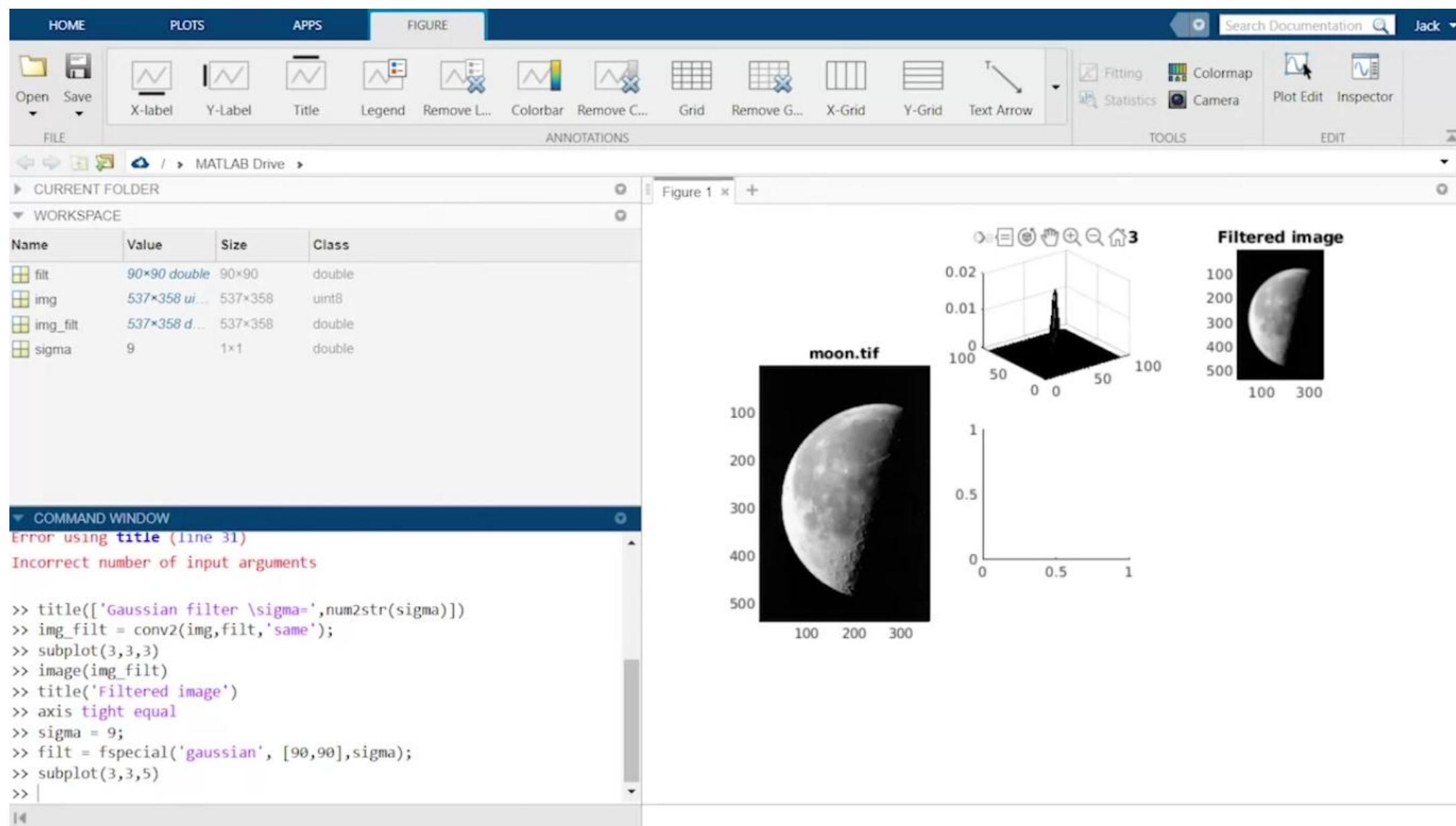


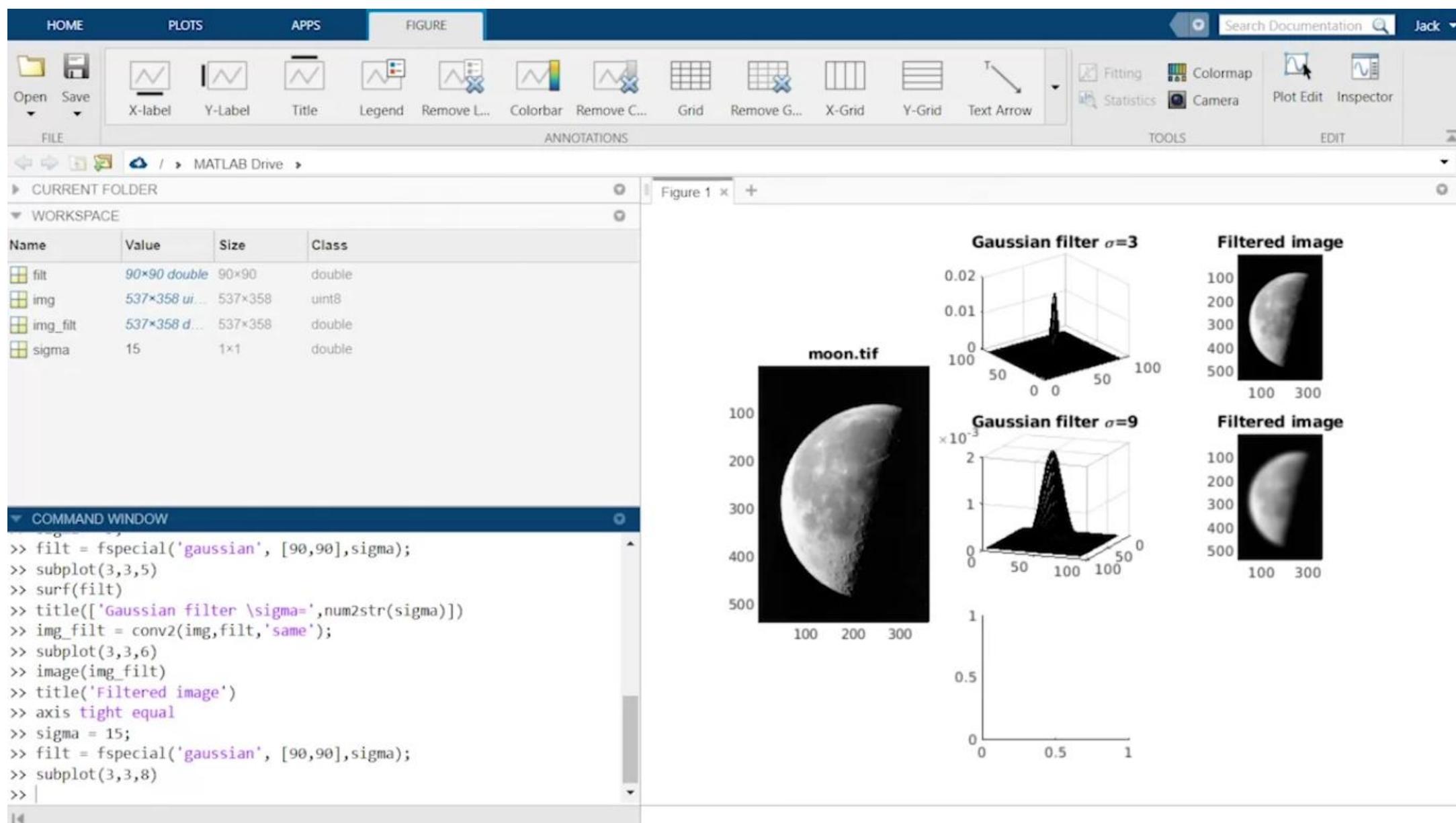
```
>> filt = fspecial('gaussian',[20,20],3);  
>> surf(filt)
```

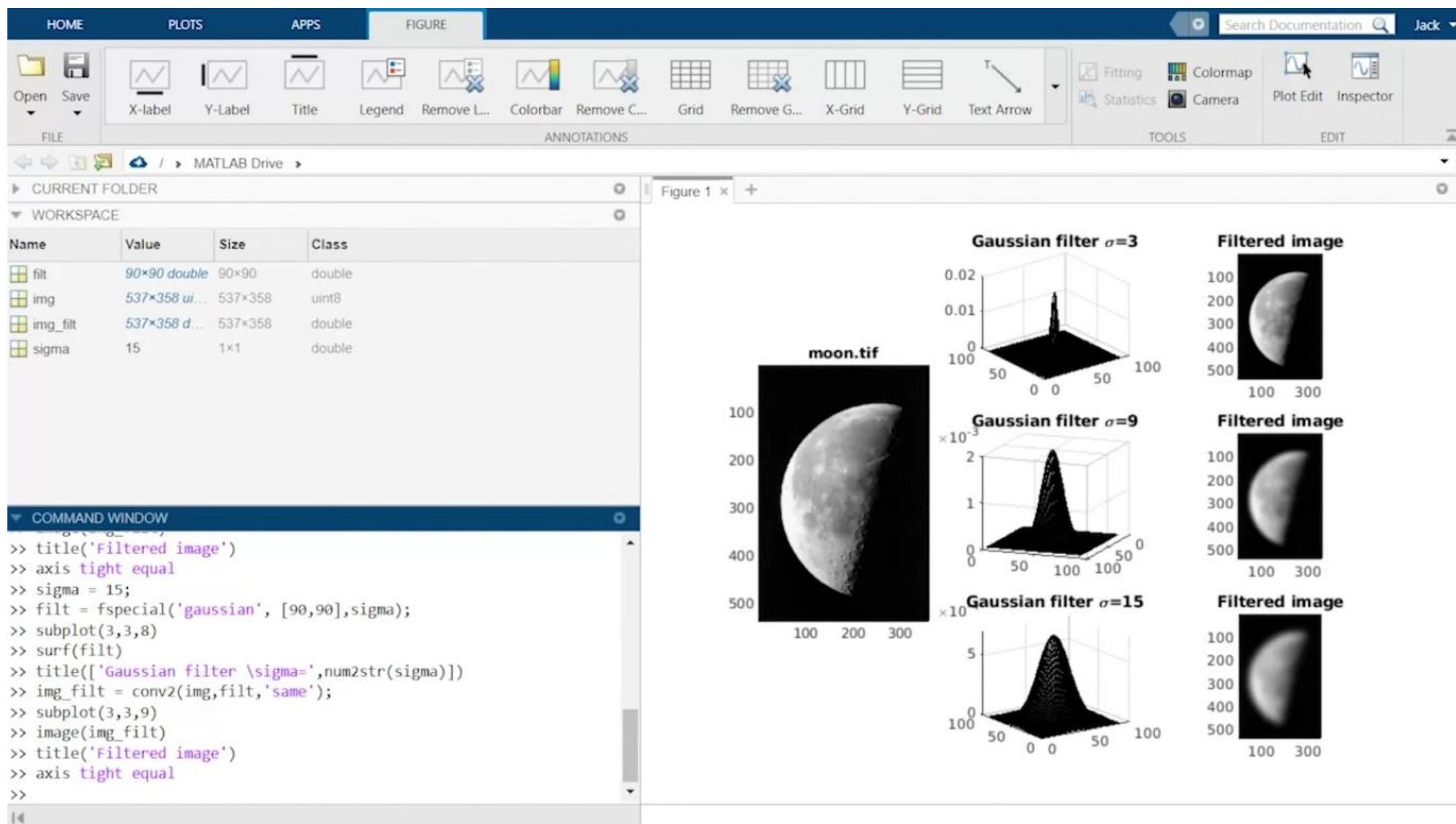


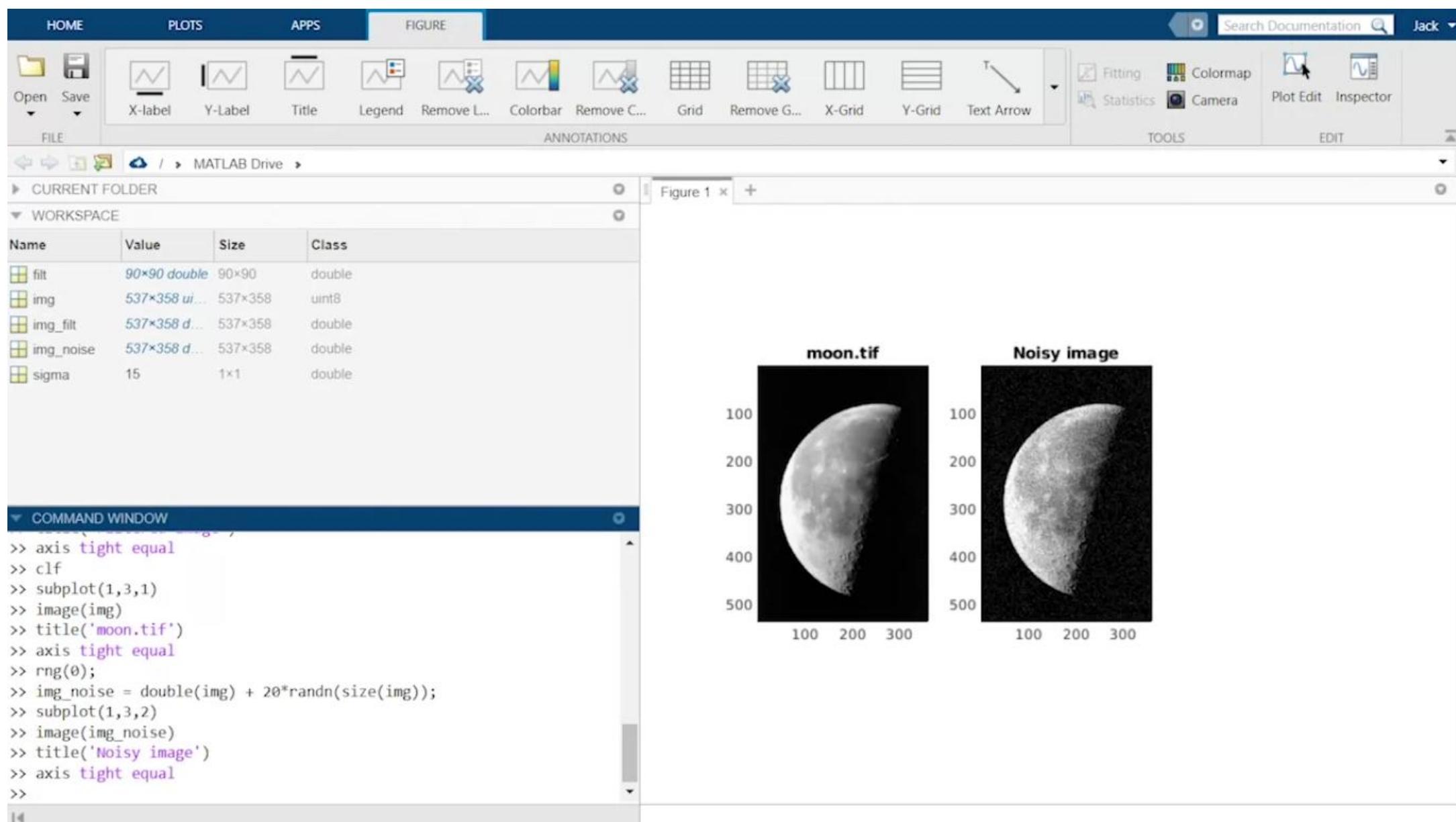
```
>> imfilt = conv2(img,filt,'same');
```

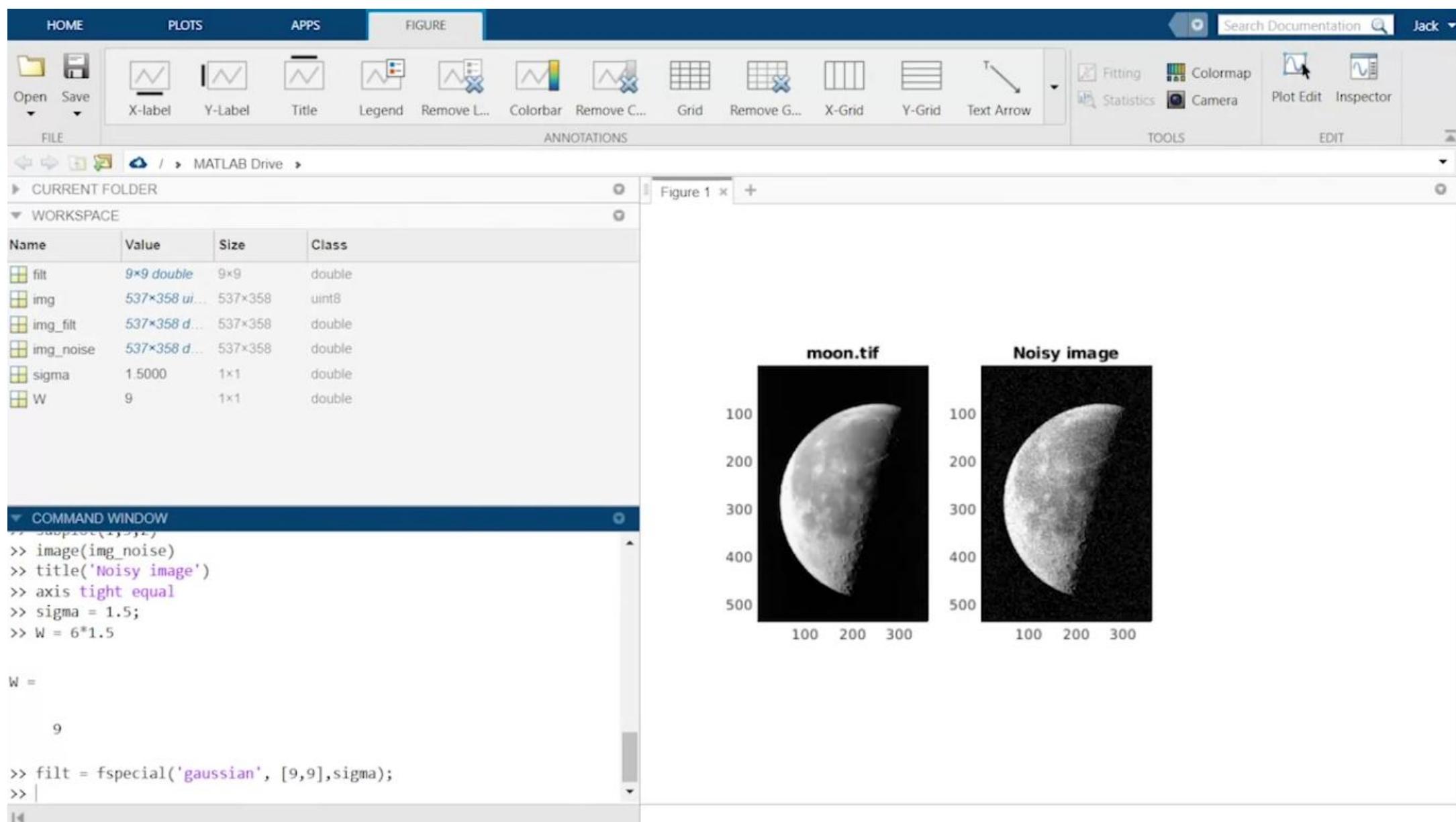


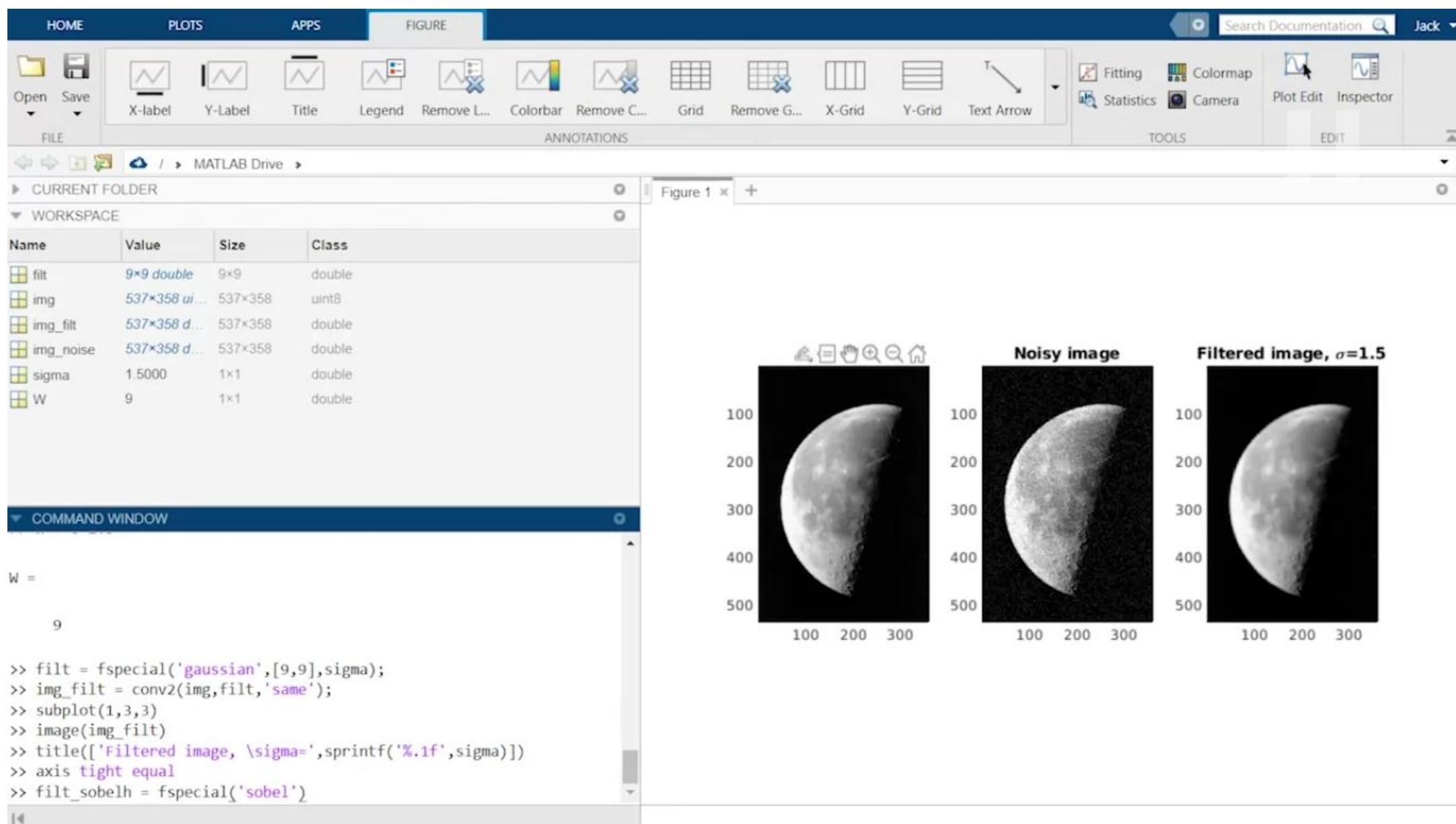


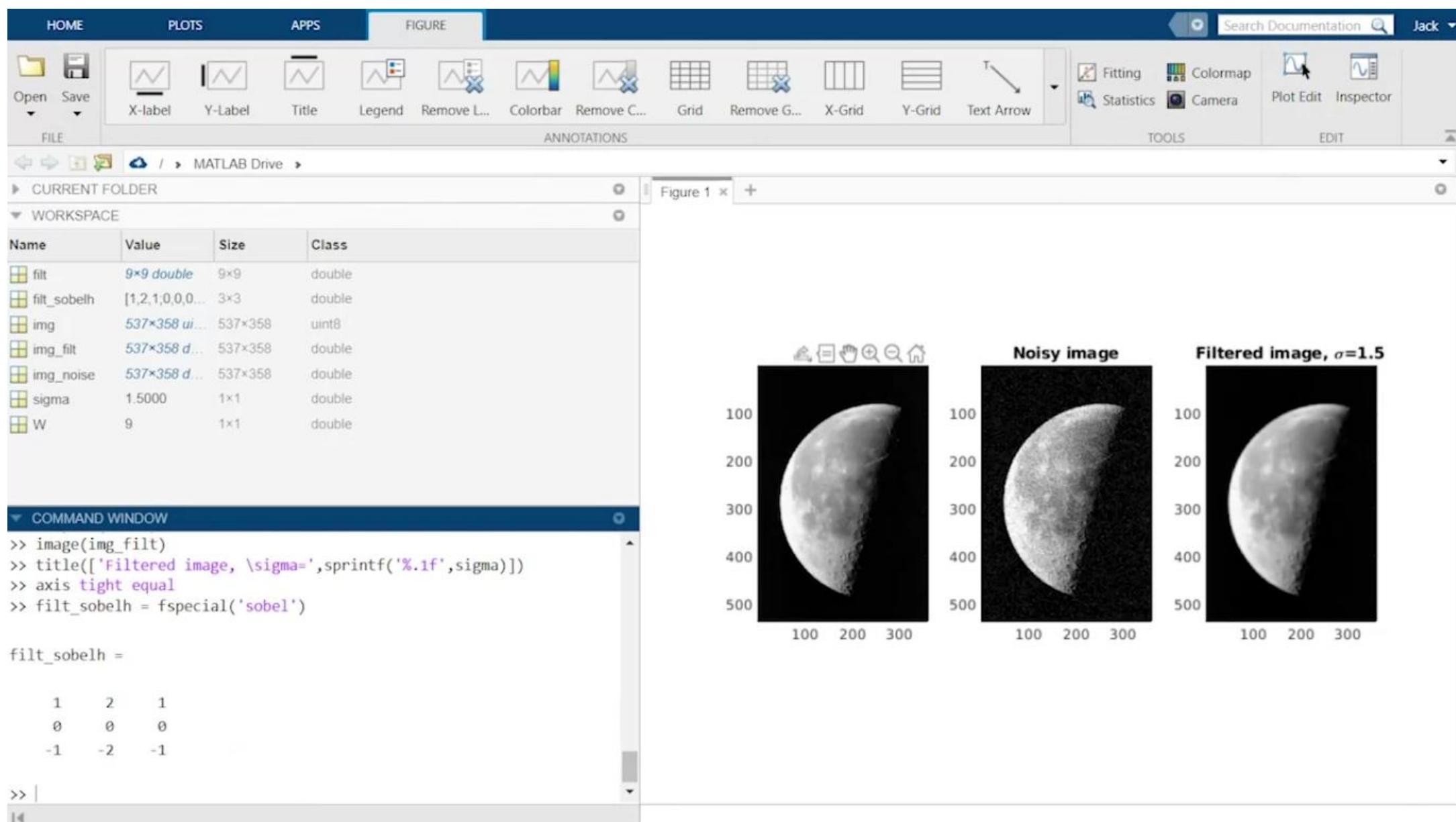


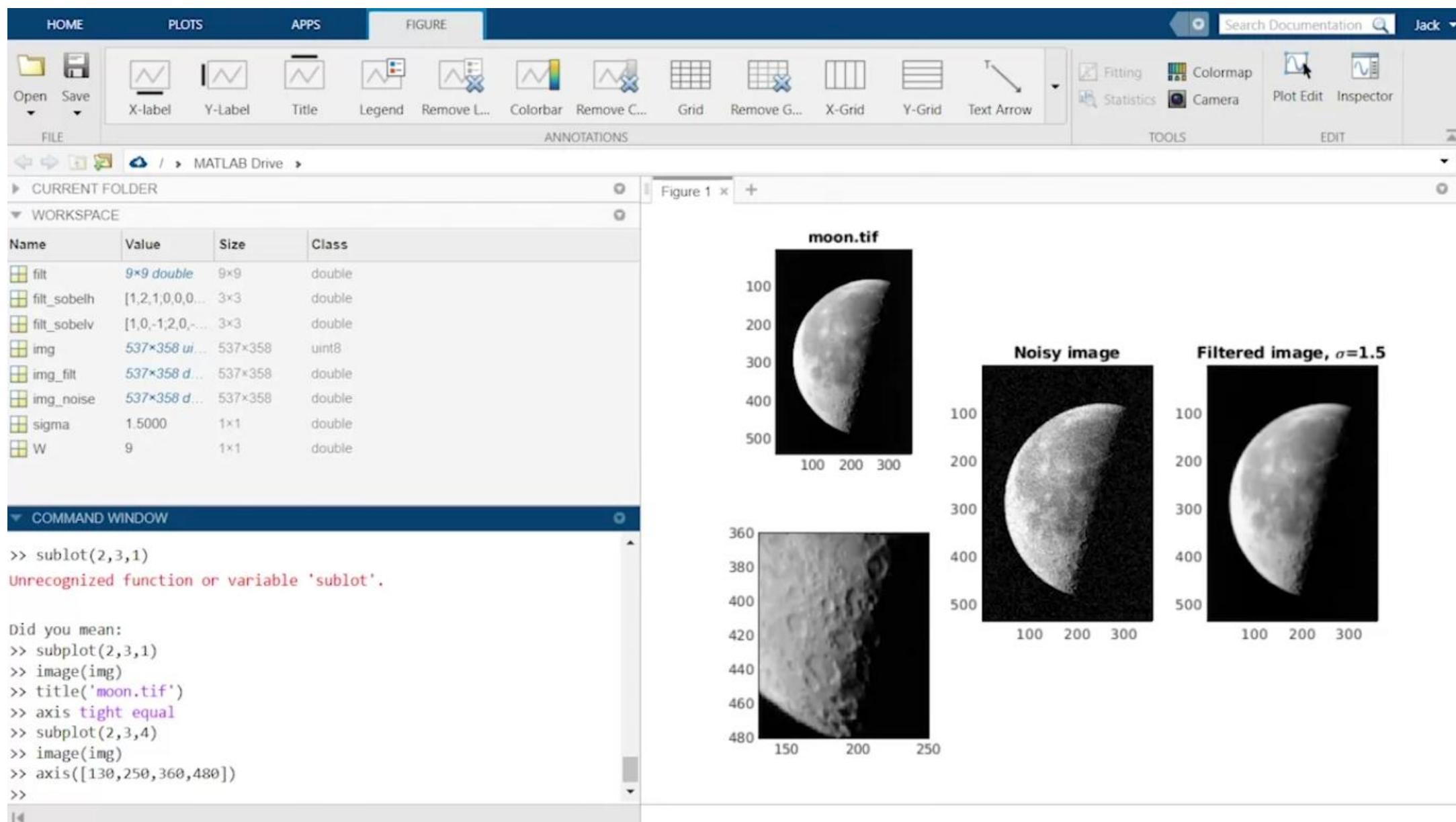


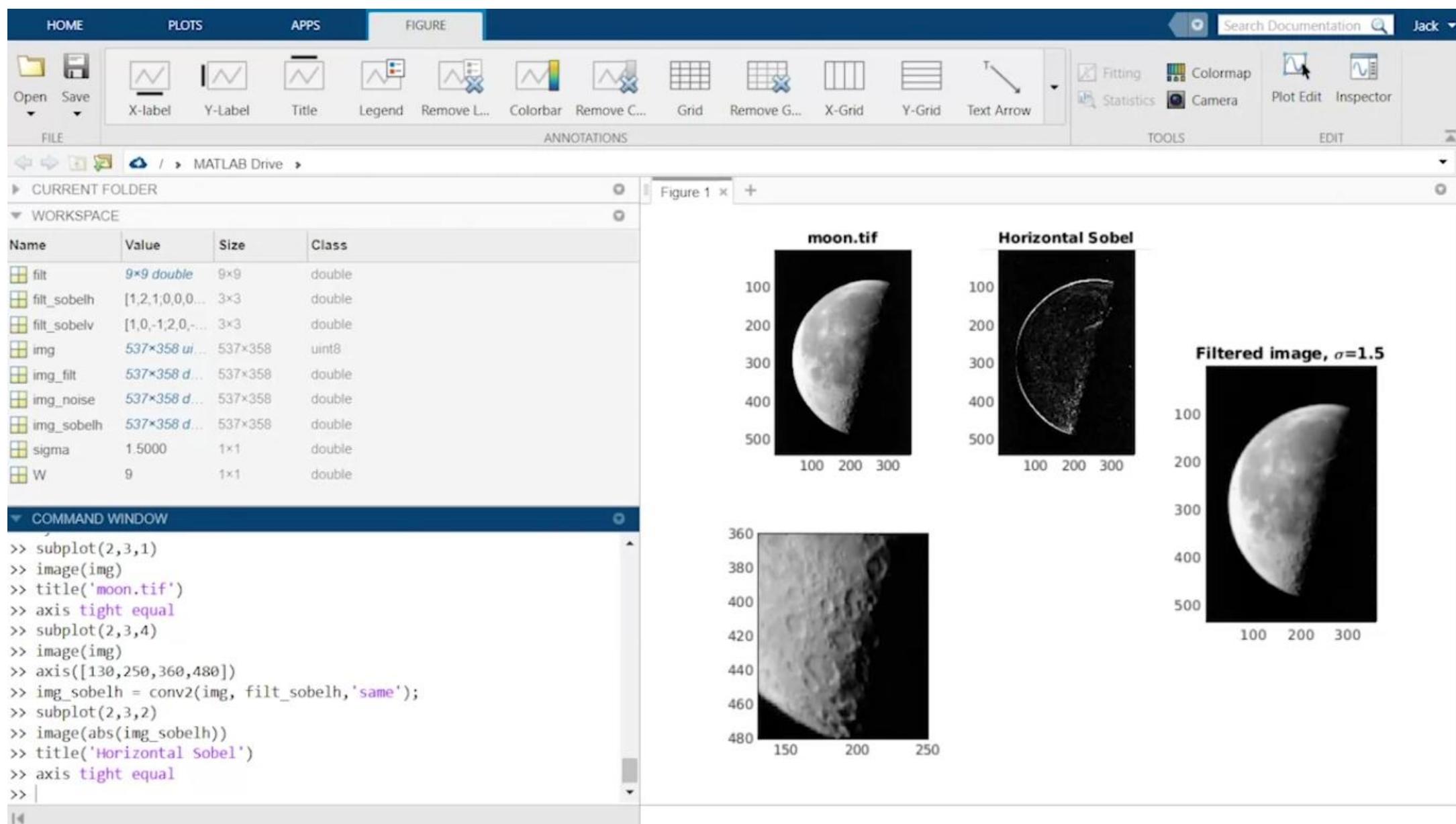












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Colorbar



Remove C...



Grid



Remove G...



X-Grid



Y-Grid



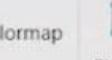
Text Arrow



Fitting



Colormap



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CURRENT FOLDER

WORKSPACE

Name	Value	Size	Class
filter	9x9 double	9x9	double
filter_sobelh	[1,2,1;0,0,0;...]	3x3	double
filter_sobelv	[1,0,-1;2,0,-...]	3x3	double
img	537x358 uint8	537x358	uint8
img_filter	537x358 double	537x358	double
img_noise	537x358 double	537x358	double
img_sobelh	537x358 double	537x358	double
img_sobelv	537x358 double	537x358	double
sigma	1.5000	1x1	double
W	9	1x1	double

COMMAND WINDOW

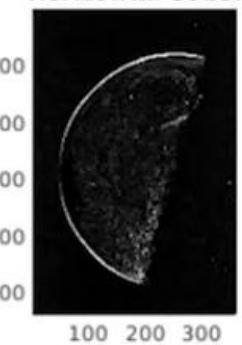
```
>> axis tight equal
>> subplot(2,3,5)
>> image(abs(img_sobelh))
>> axis([130,250,360,480])
>> img_sobelv = conv2(img, filter_sobelv, 'same');
>> subplot(2,3,3)
>> image(abs(img_sobelv))
>> title('Vertical Sobel')
>> axis tight equal
>> subplot(2,3,6)
>> image(abs(img_sobelv))
>> axis([130,250,360,480])
>> |
```

Figure 1

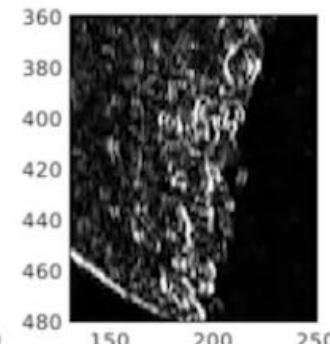
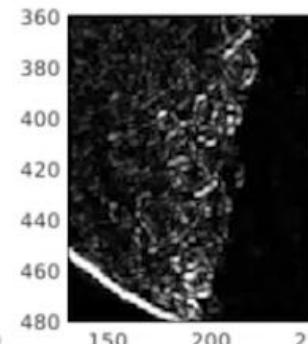
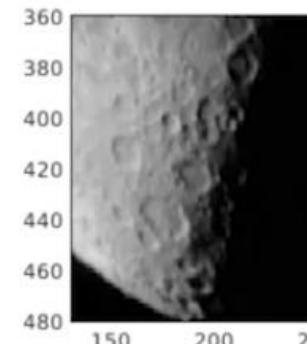
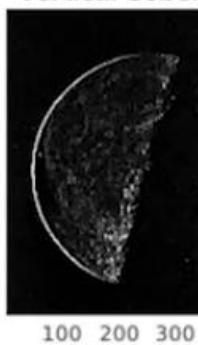
moon.tif

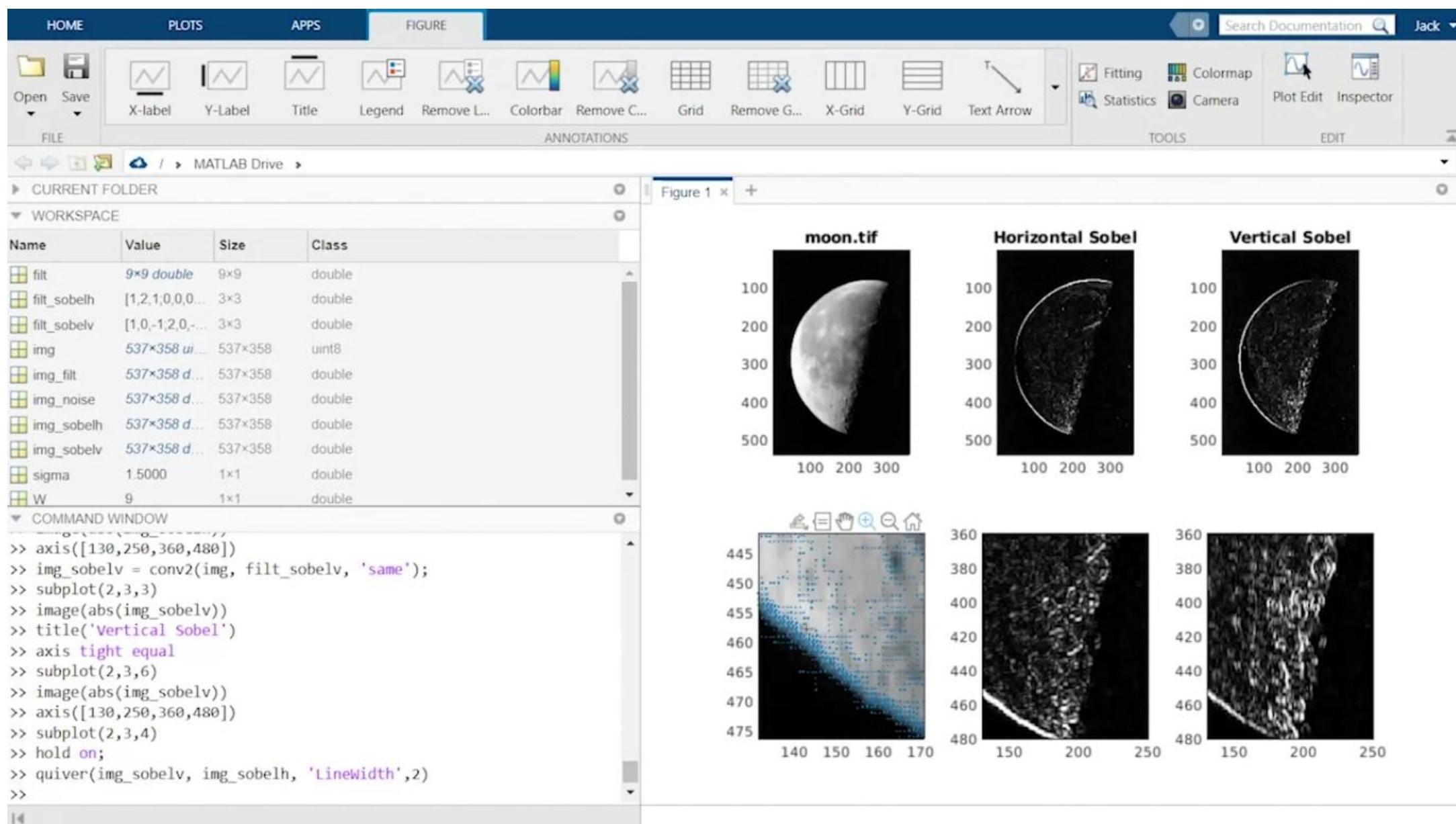


Horizontal Sobel



Vertical Sobel





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CURRENT FOLDER

WORKSPACE

Name	Value	Size	Class
filt	9×9 double	9×9	double
filt_log	5×5 double	5×5	double
filt_sobelh	[1,2,1;0,0,0;...]	3×3	double
filt_sobelv	[1,0,-1;2,0,-...]	3×3	double
img	537×358 ui...	537×358	uint8
img_filt	537×358 d...	537×358	double
img_noise	537×358 d...	537×358	double
W	9	537×358	double
W	537×358 d...	537×358	double
W	9	1×1	double

COMMAND WINDOW

```
>> quiver(img_sobelv, img_sobelh, 'LineWidth',2)
>> filt_log = fspecial('log')
```

filt_log =

0.0448	0.0468	0.0564	0.0468	0.0448
0.0468	0.3167	0.7146	0.3167	0.0468
0.0564	0.7146	-4.9048	0.7146	0.0564
0.0468	0.3167	0.7146	0.3167	0.0468
0.0448	0.0468	0.0564	0.0468	0.0448

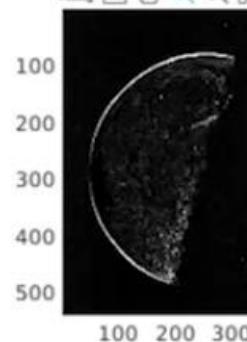
>> img_log = conv2(img, filt_log, 'same');

Figure 1

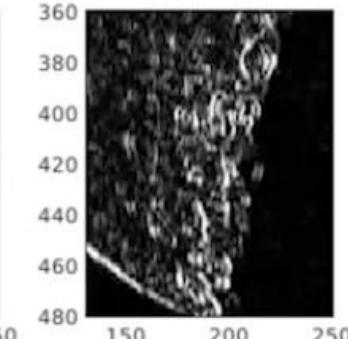
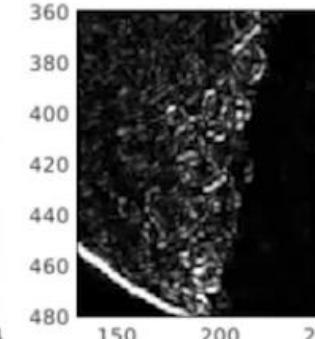
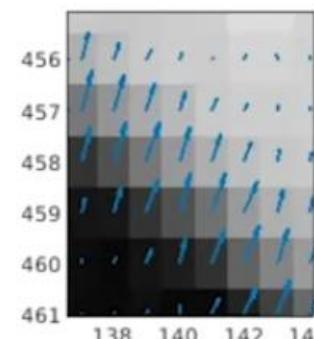
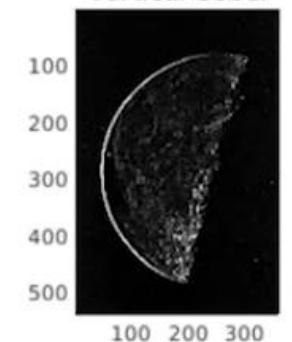
moon.tif

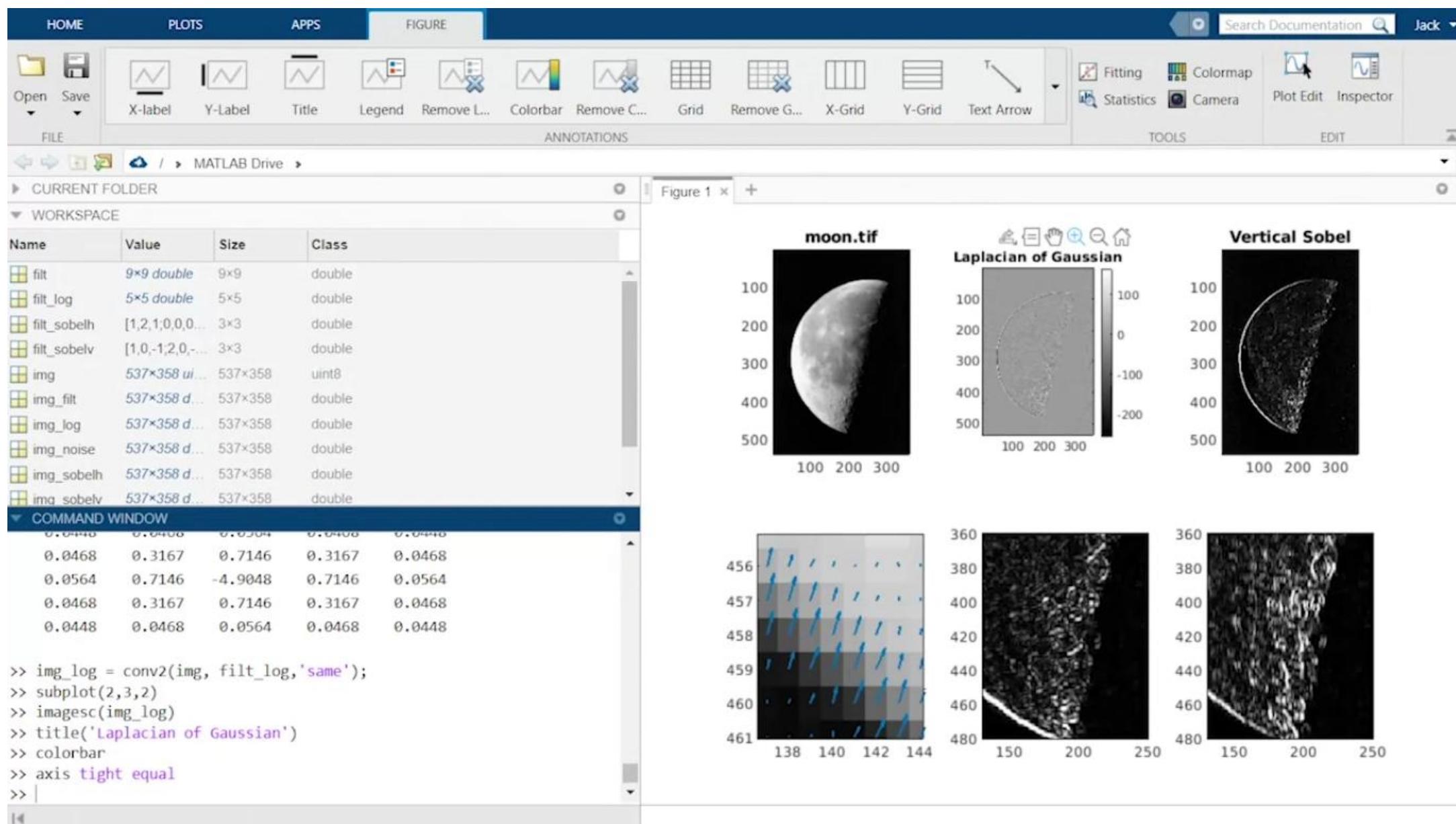


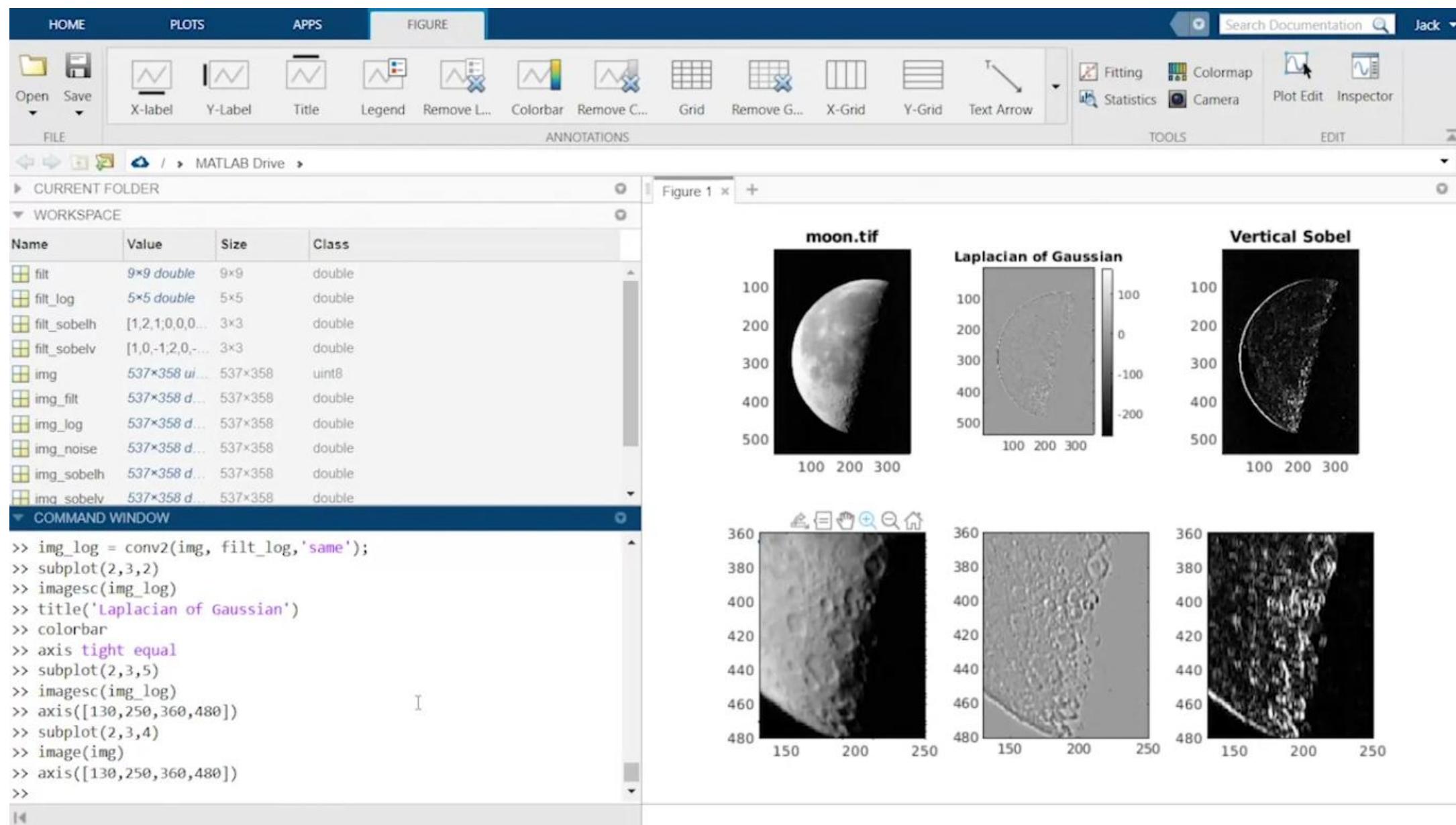
Vertical Sobel



Vertical Sobel







HOME

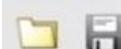
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CURRENT FOLDER

WORKSPACE

Name	Value	Size	Class
filter	9x9 double	9x9	double
filter_log	5x5 double	5x5	double
filter_sobelh	[1,2,1;0,0,0;0,0,1]	3x3	double
filter_sobelv	[1,0,-1;2,0,-2]	3x3	double
img	537x358 uint8	537x358	uint8
img_filter	537x358 double	537x358	double
img_log	537x358 double	537x358	double
W	9	537x358	double
img_shrp	537x358 double	537x358	double
W	537x358 double	537x358	double

COMMAND WINDOW

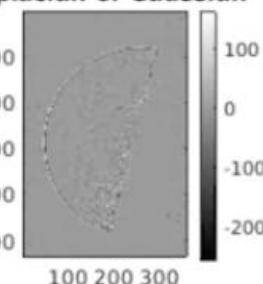
```
>> axis([130,250,360,480])
>> subplot(2,3,4)
>> image(img)
>> axis([130,250,360,480])
>> img_shrp = double(img) - 1*img_log;
>> subplot(2,3,3)
>> image(img_shrp)
>> title('Sharpened Image')
>> axis tight equal
>> subplot(2,3,6)
>> image(img_shrp)
>> axis([130,250,360,480])
>> |
```

Figure 1

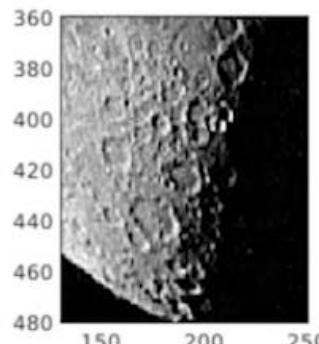
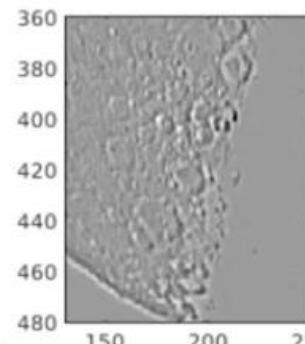
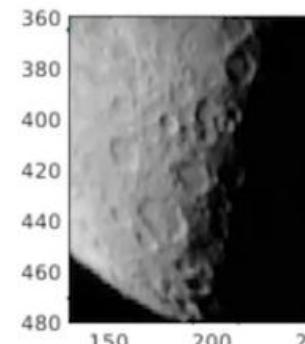
moon.tif

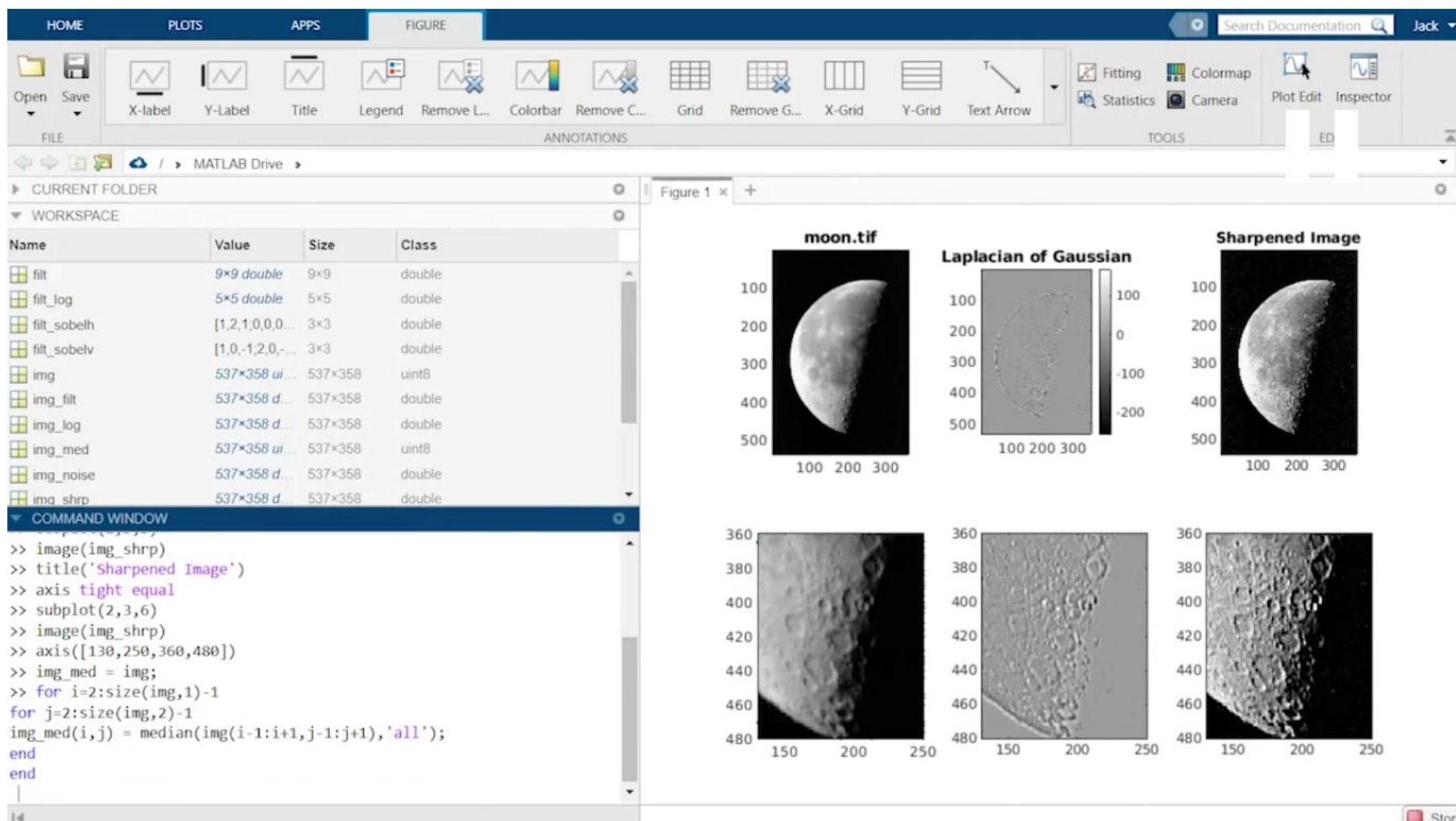


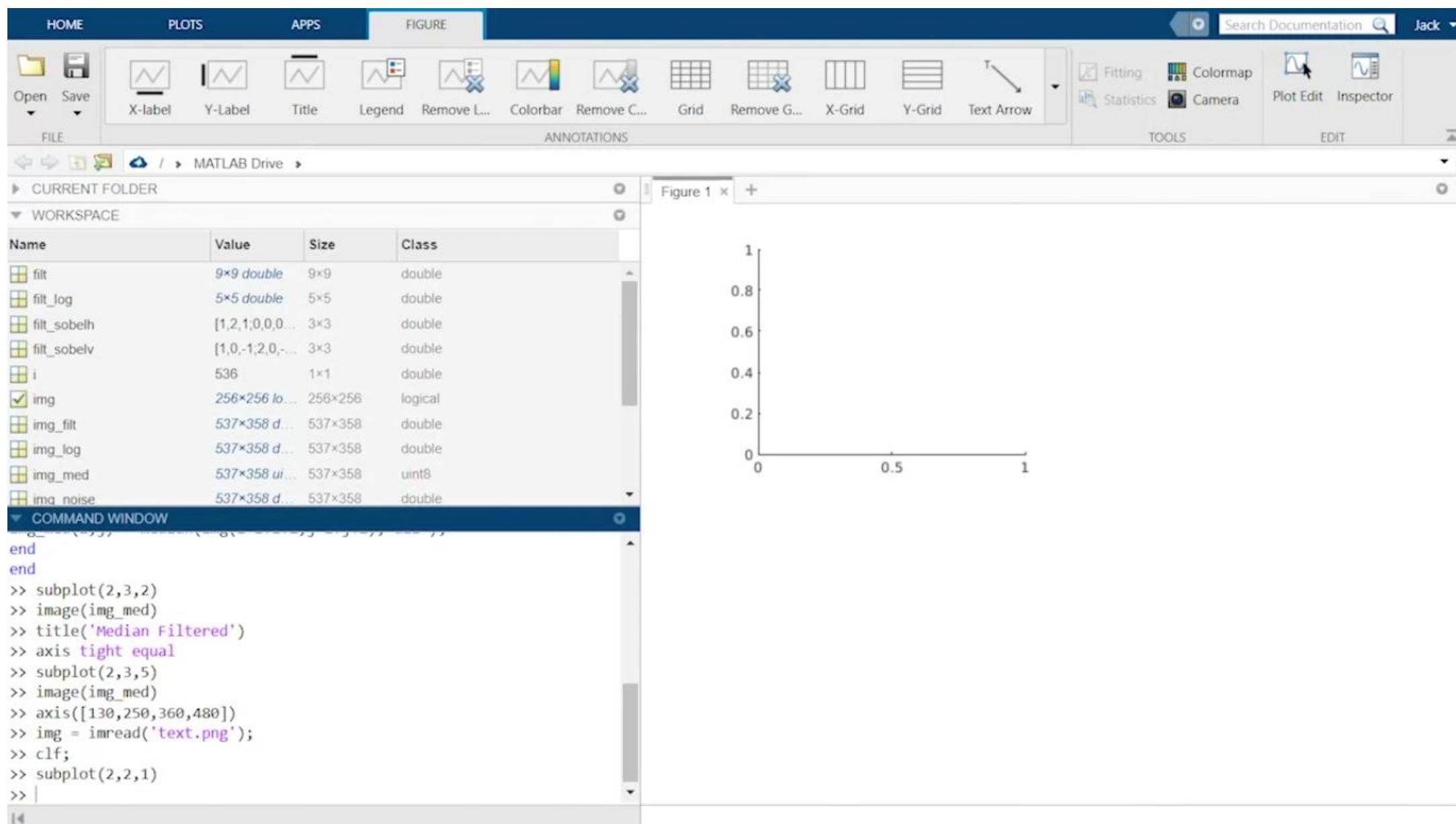
Laplacian of Gaussian

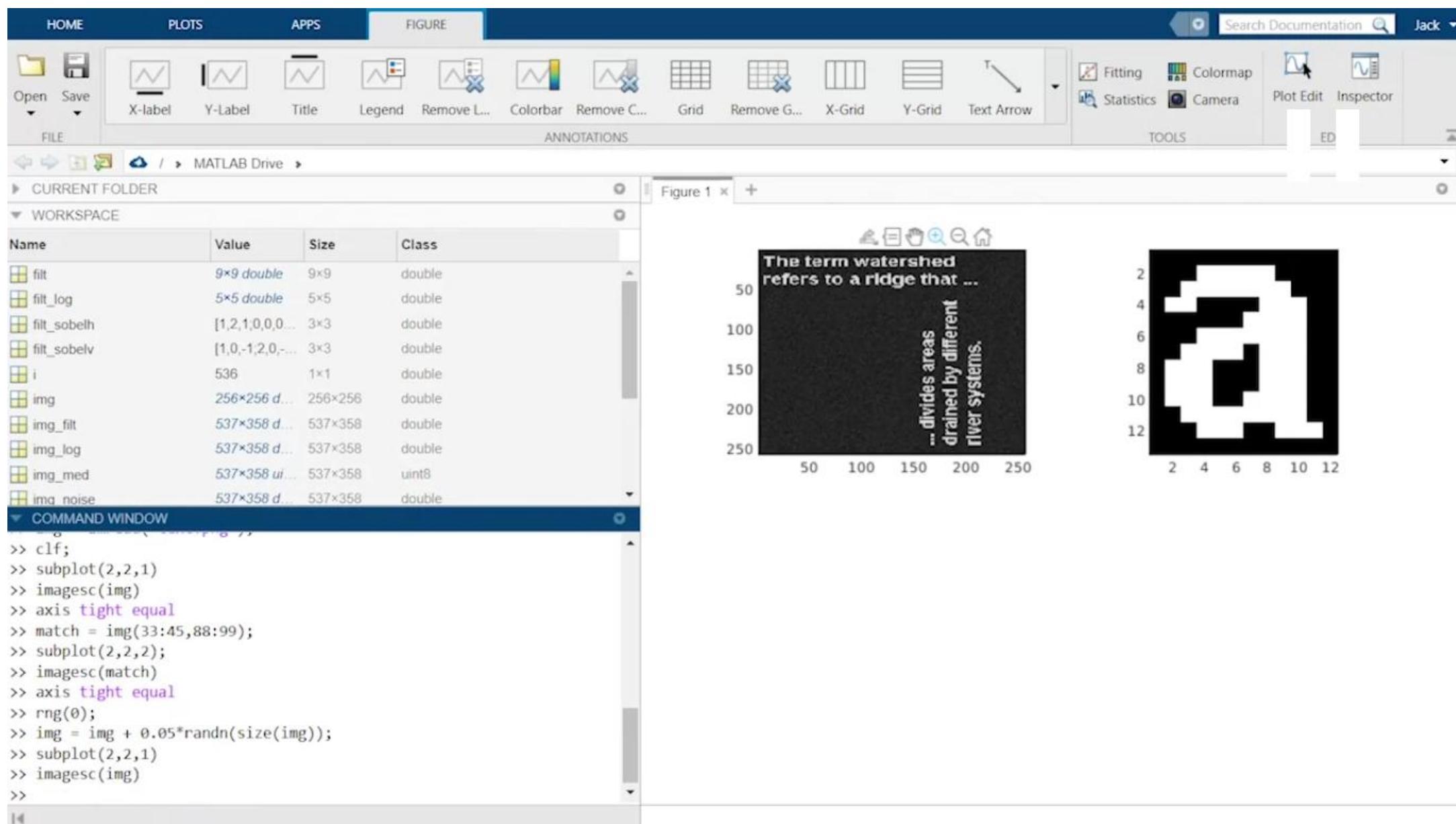


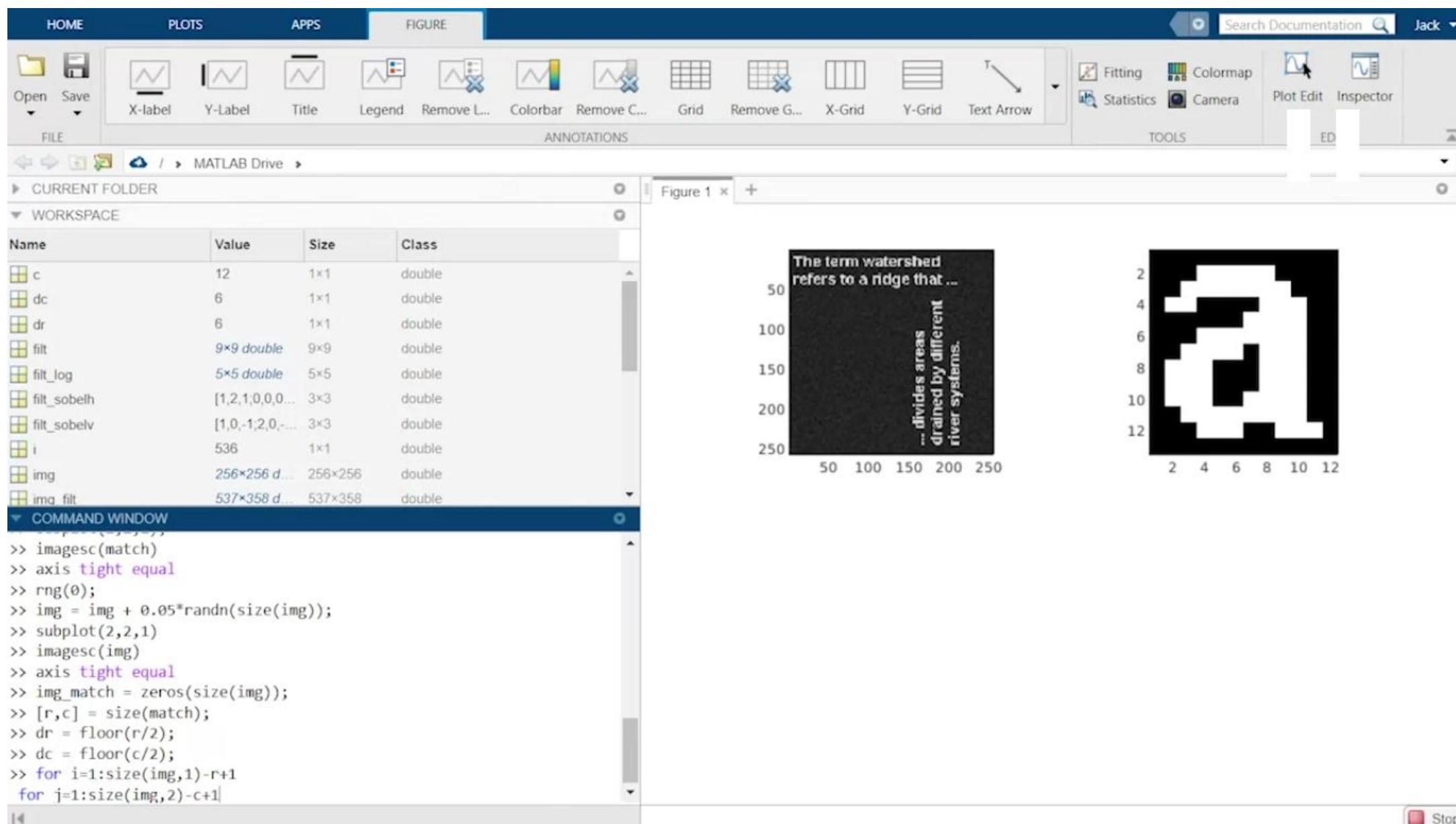
Sharpened Image

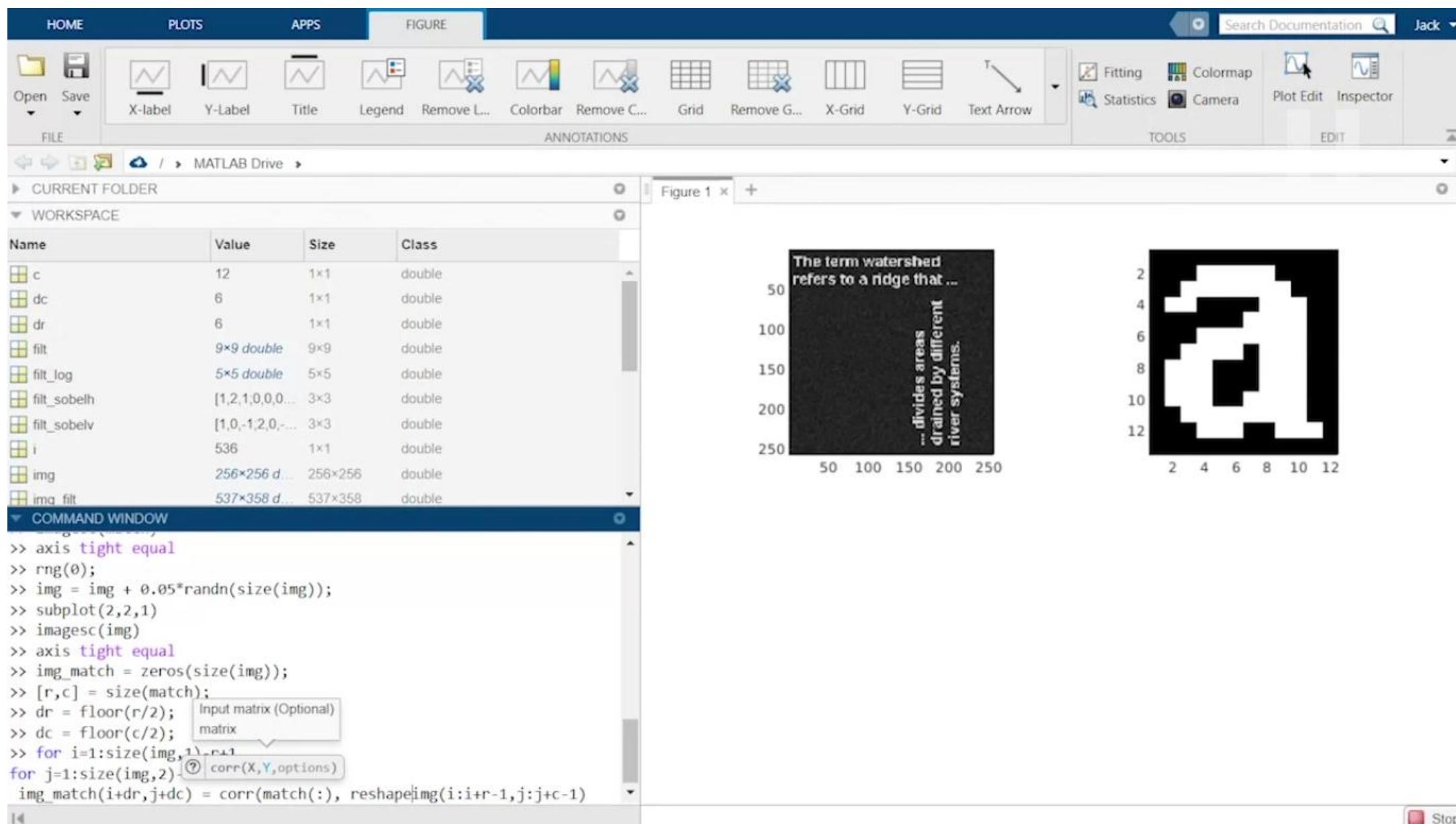


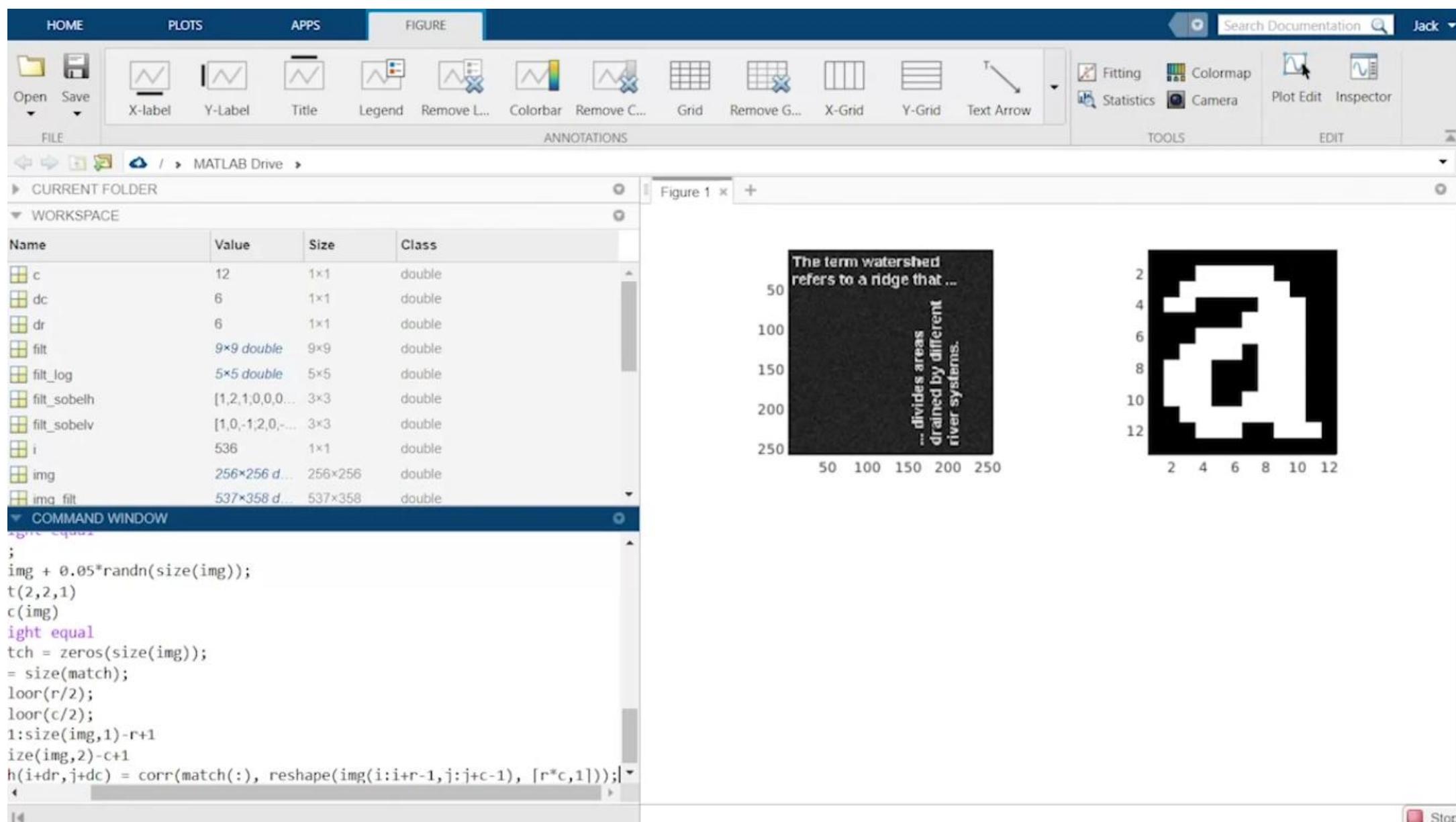


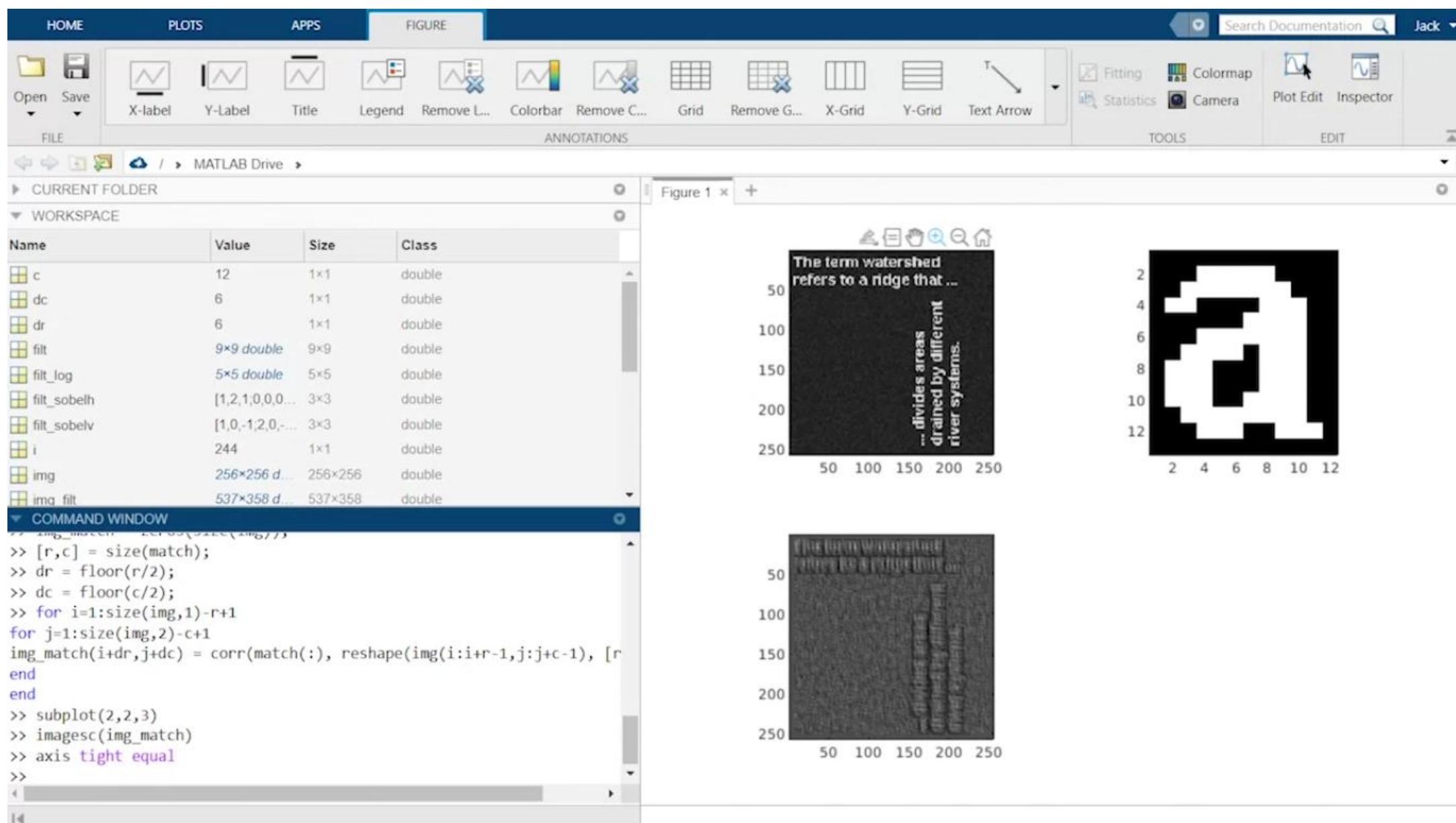


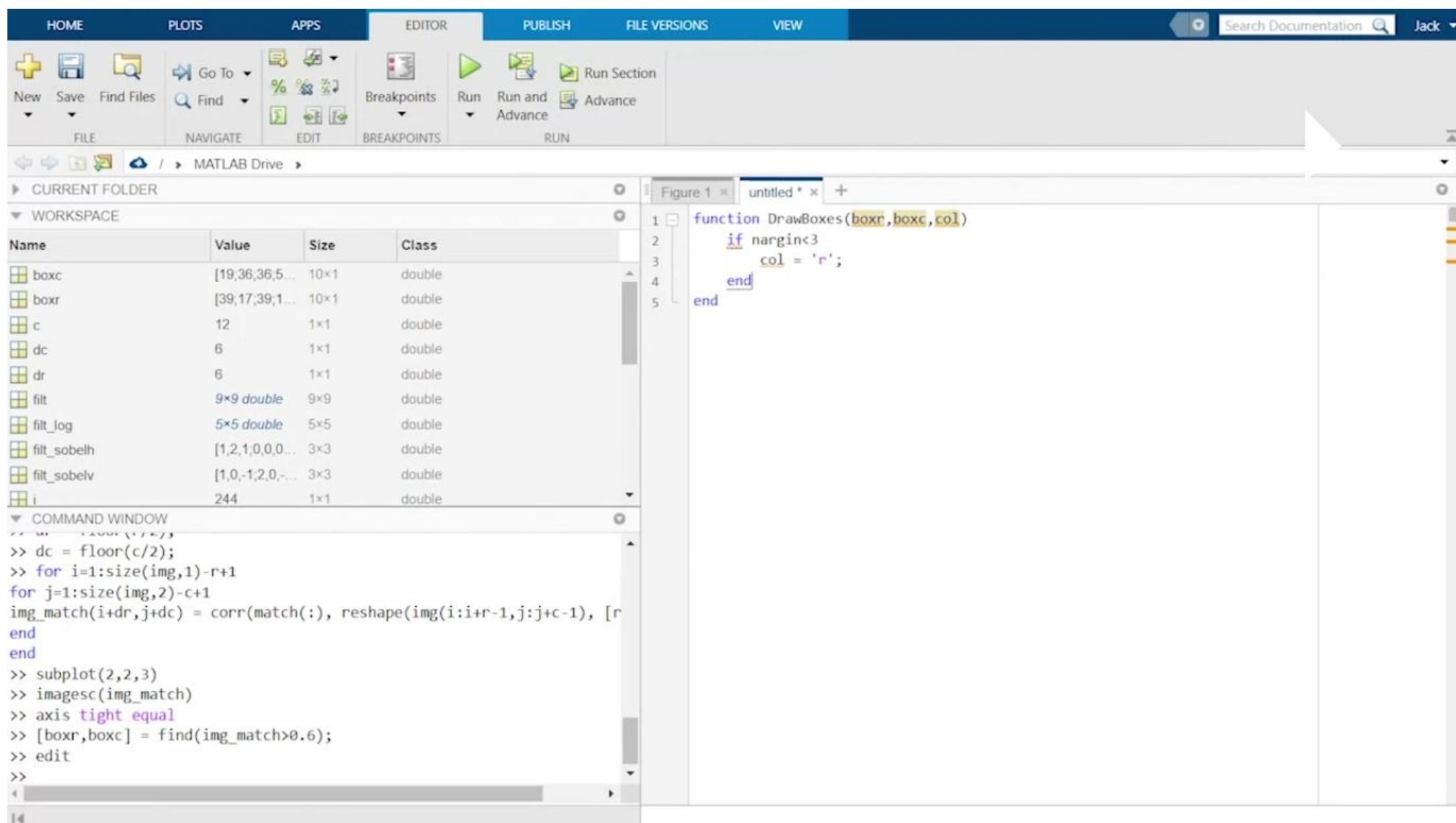












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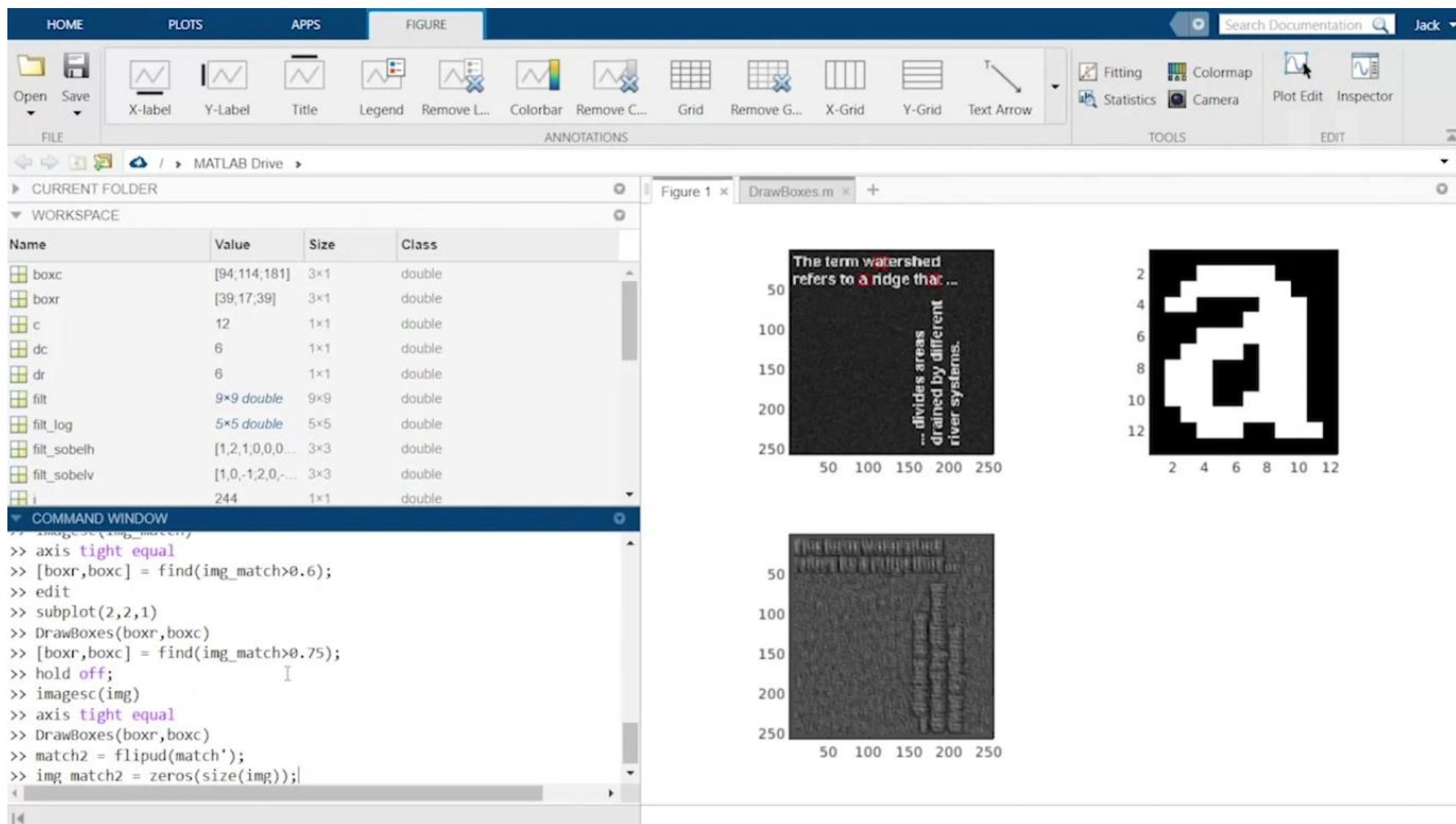
Name	Value	Size	Class
boxc	[19,36,36,5...]	10x1	double
boxr	[39,17;39,1...]	10x1	double
c	12	1x1	double
dc	6	1x1	double
dr	6	1x1	double
filt	9x9 double	9x9	double
filt_log	5x5 double	5x5	double
filt_sobelh	[1,2,1;0,0,0...]	3x3	double
filt_sobelv	[1,0,-1;2,0,-...]	3x3	double
i	244	1x1	double

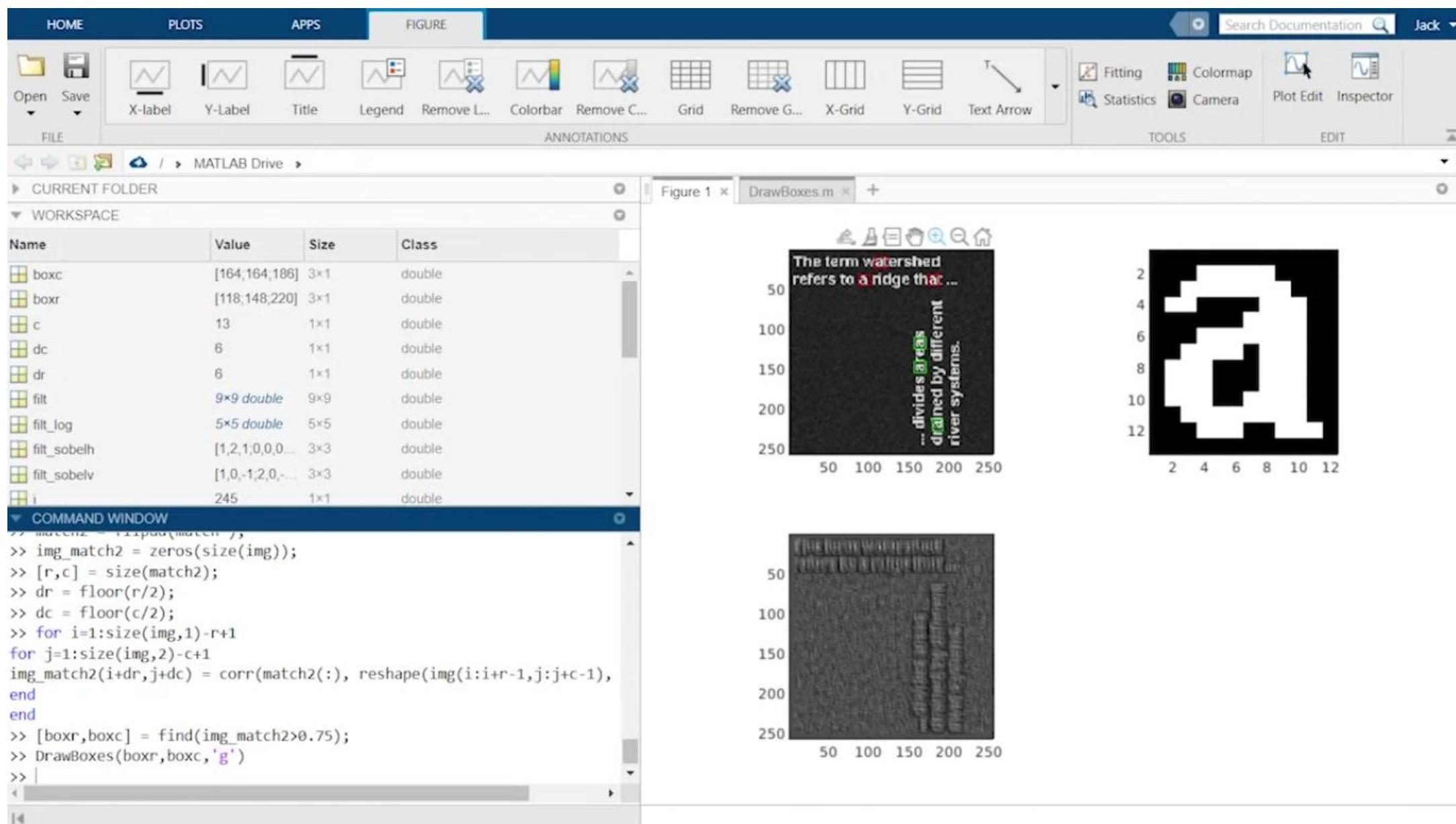
COMMAND WINDOW

```
>> dc = floor(c/2);
>> for i=1:size(img,1)-r+1
for j=1:size(img,2)-c+1
img_match(i+dr,j+dc) = corr(match(:,), reshape(img(i:i+r-1,j:j+c-1), [r
end
end
>> subplot(2,2,3)
>> imagesc(img_match)
>> axis tight equal
>> [boxr,boxc] = find(img_match>0.6);
>> edit
>>
```

Figure 1 x untitled * x +

```
function DrawBoxes(boxr,boxc,col)
if margin<3
    col = 'r';
end
verts_boxc = 7*[-1, 1, 1,-1,-1];
verts_boxr = 7*[-1,-1, 1, 1,-1];
hold on;
for i=1:length(boxr)
    plot(boxc(i) + verts_boxc, verts_boxr + boxr(i), col);
end
end
```







Introduction to Data, Signal, and Image Analysis with MATLAB®

Lesson 4.5 Image Segmentation

Jack Noble

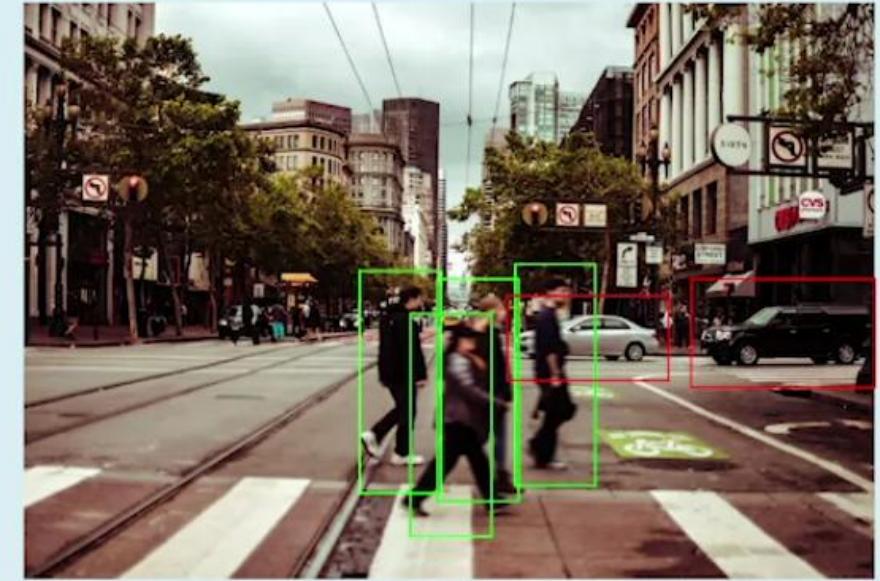
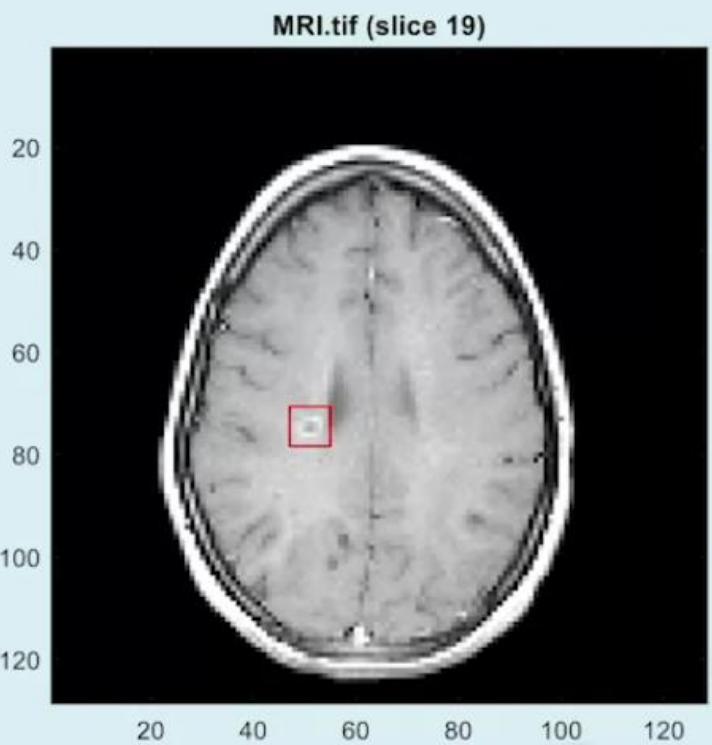
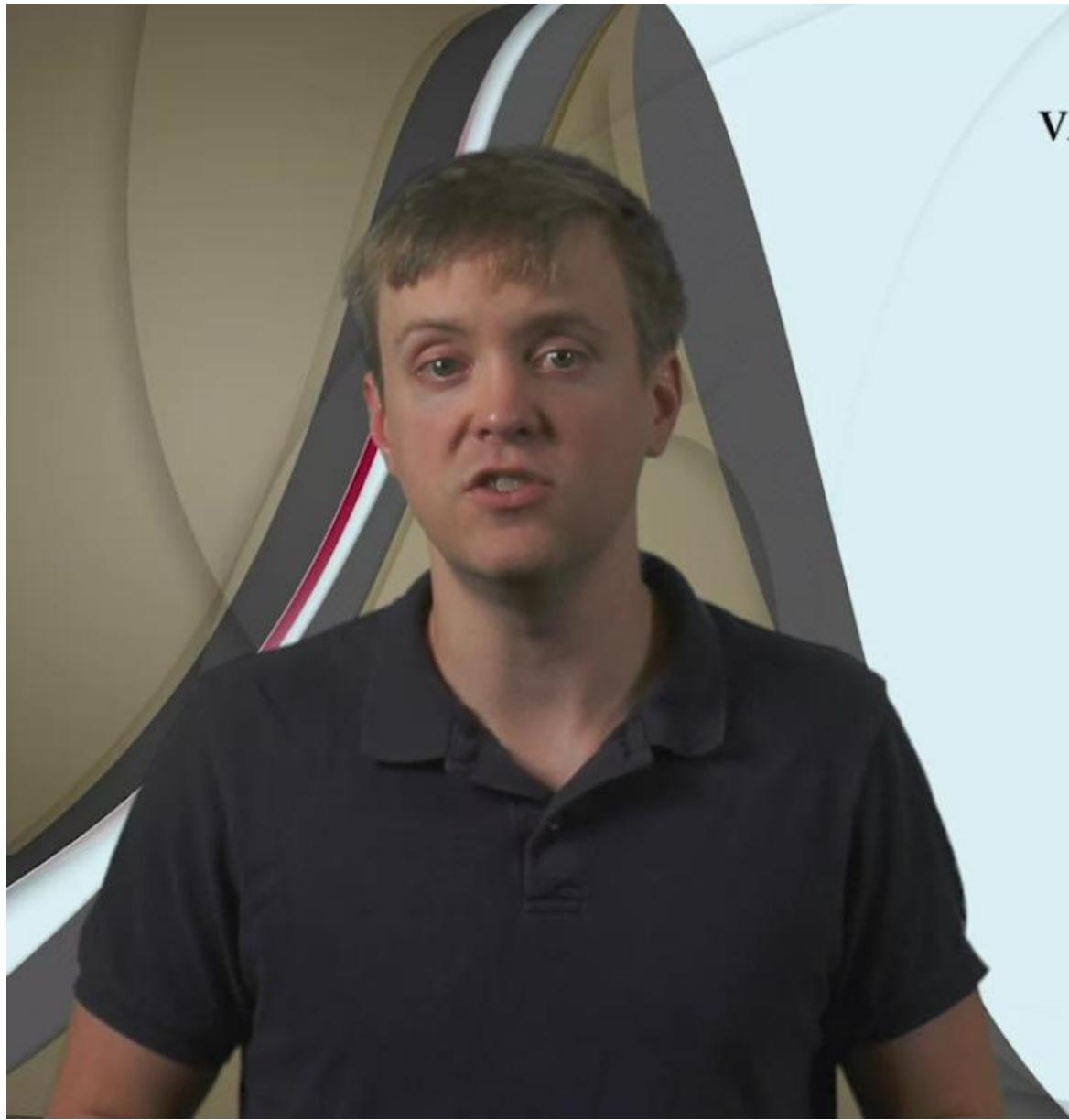
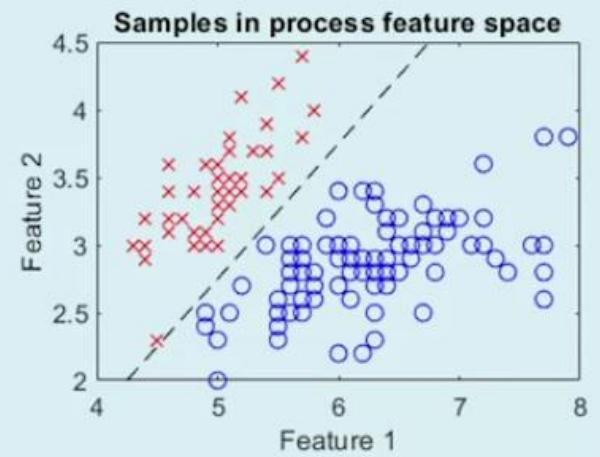
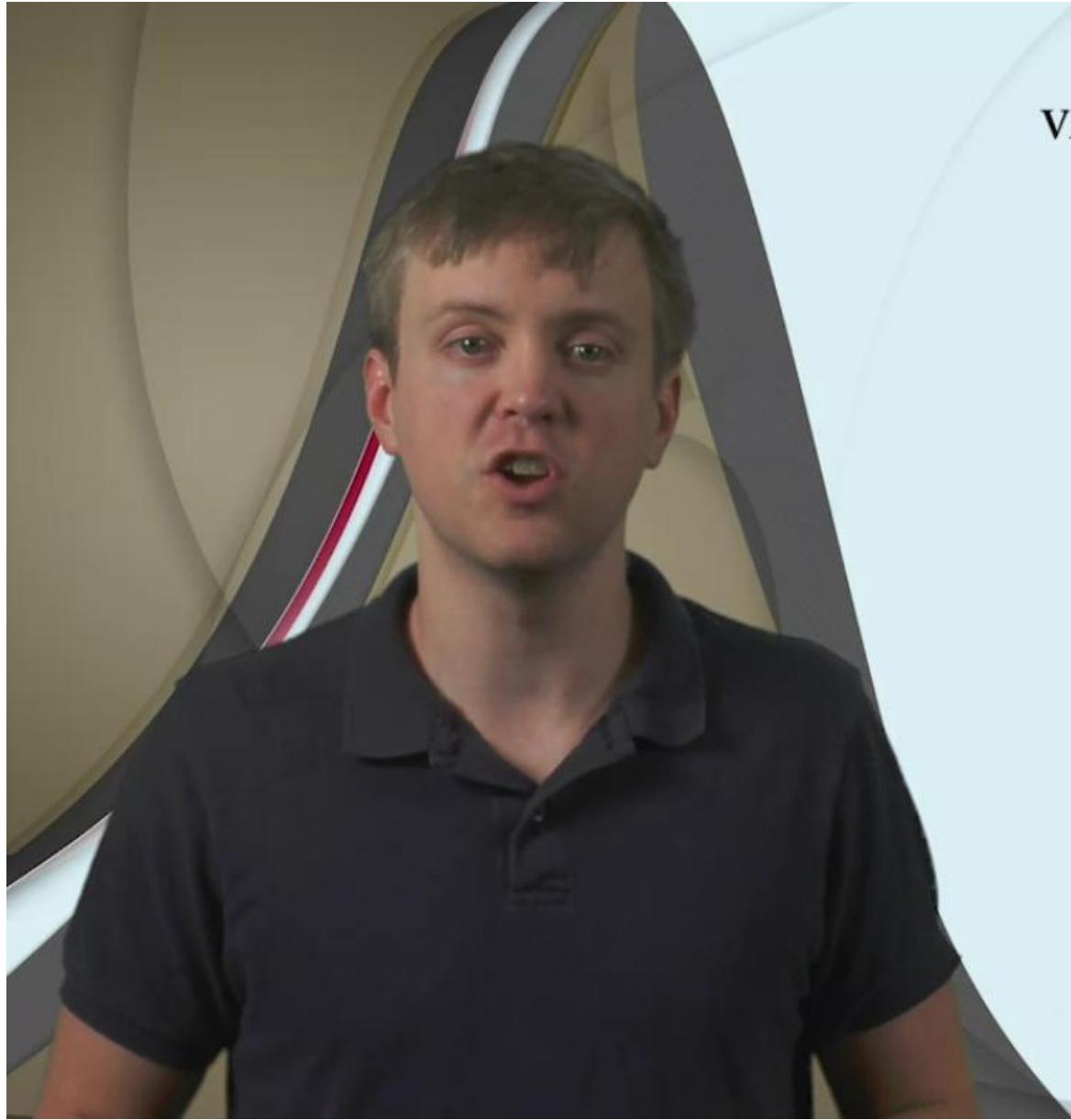
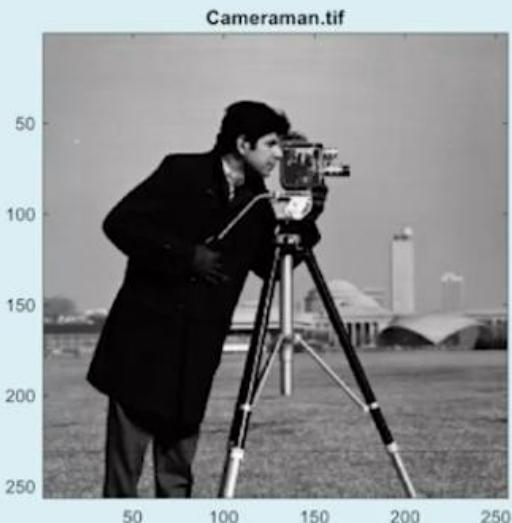


Photo by Quintin Gellar, <https://www.pexels.com/photo/blur-buildings-california-city-631042/>

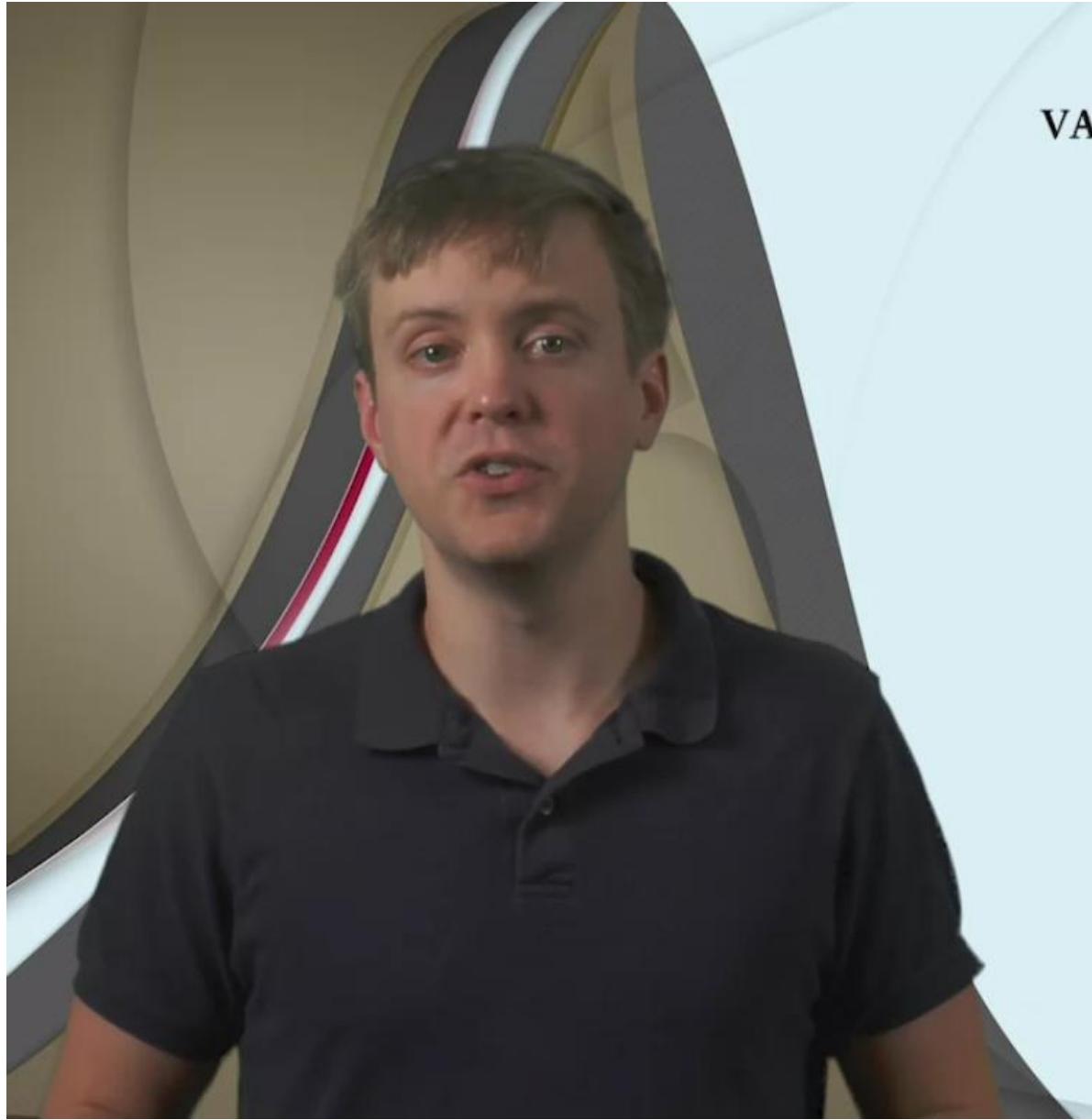






```
>> img = imread('cameraman.tif');
>> intensities = img(:);
>> size(intensities)

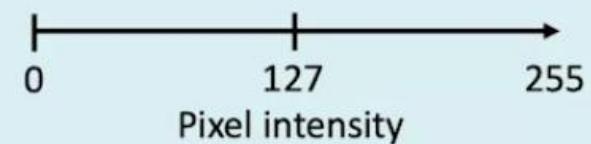
ans =
    65536         1
```

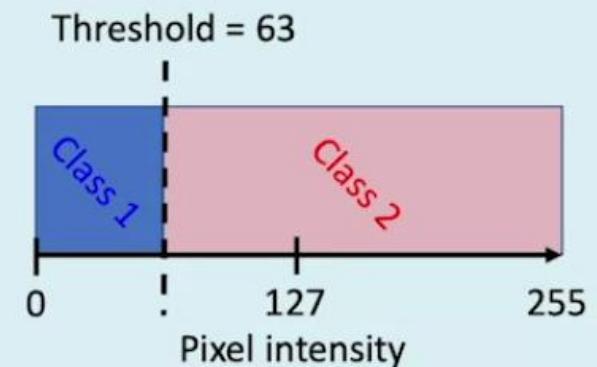


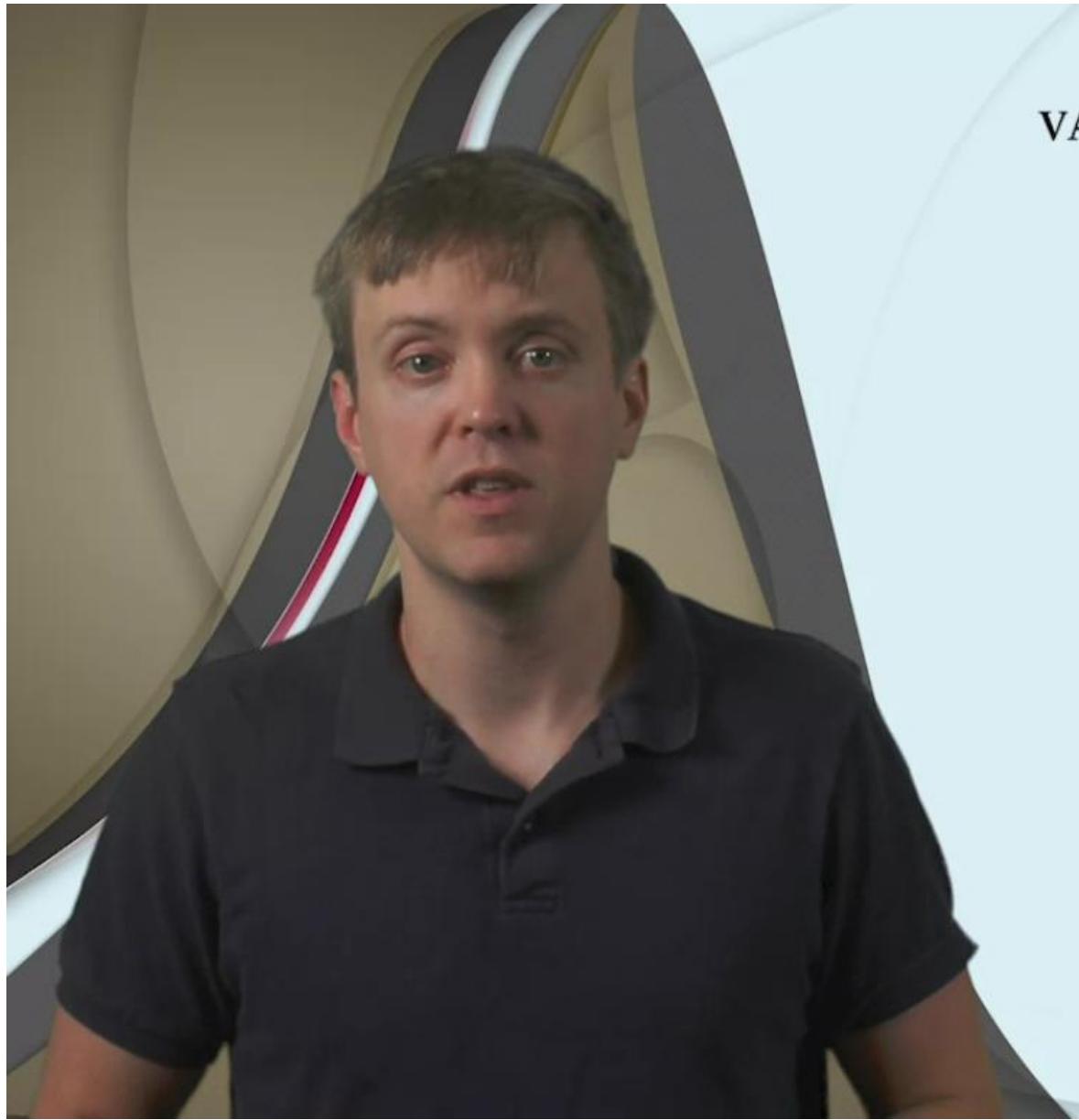
VANDERBILT



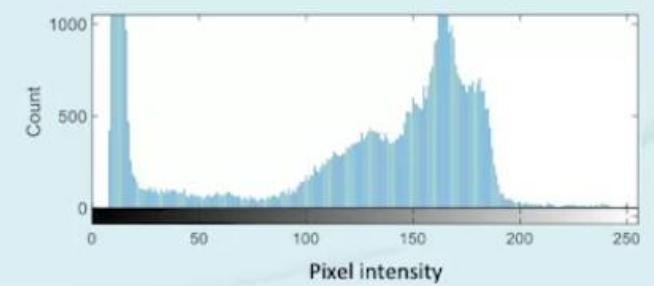
03:11 / 54:53
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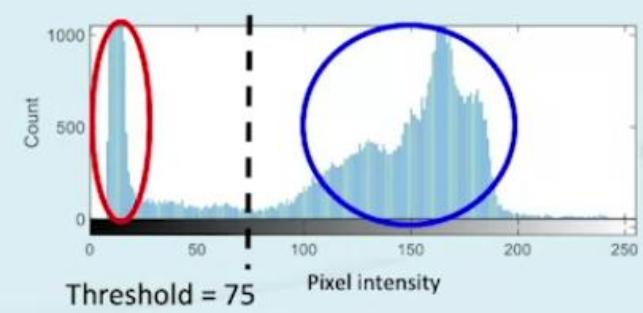
Cameraman.tif



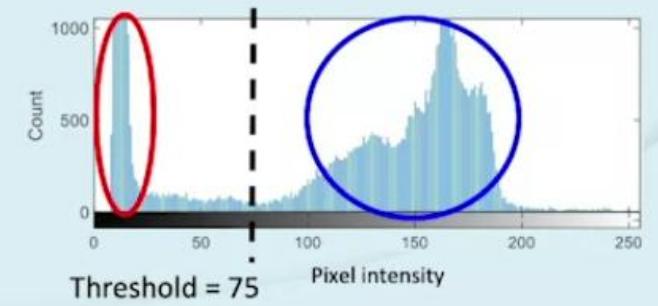
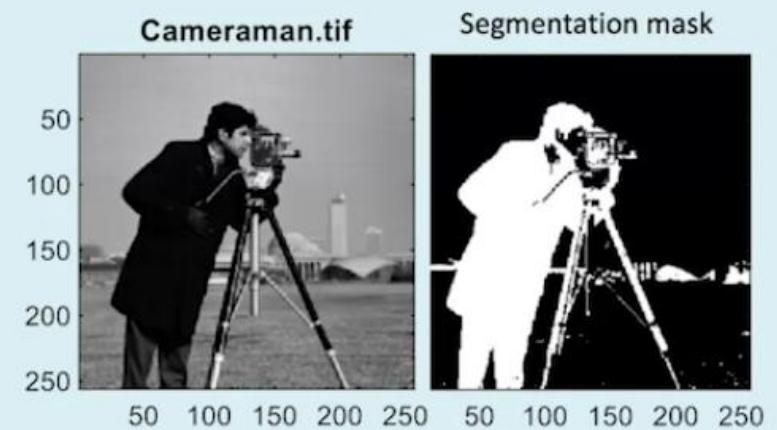


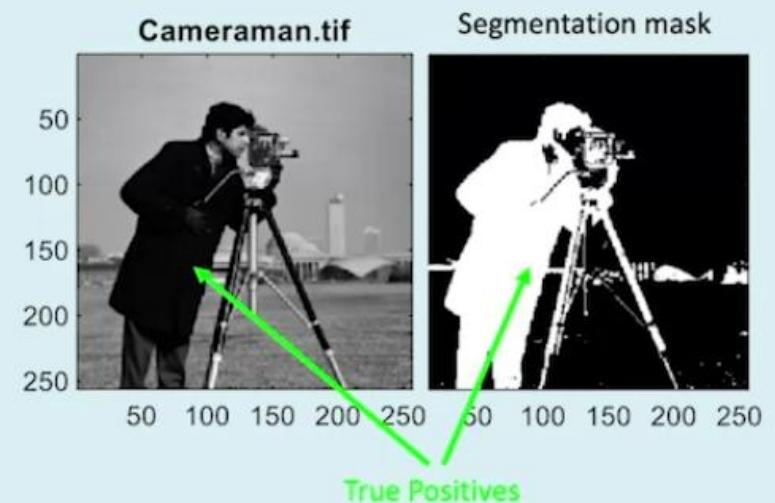
VANDERBILT

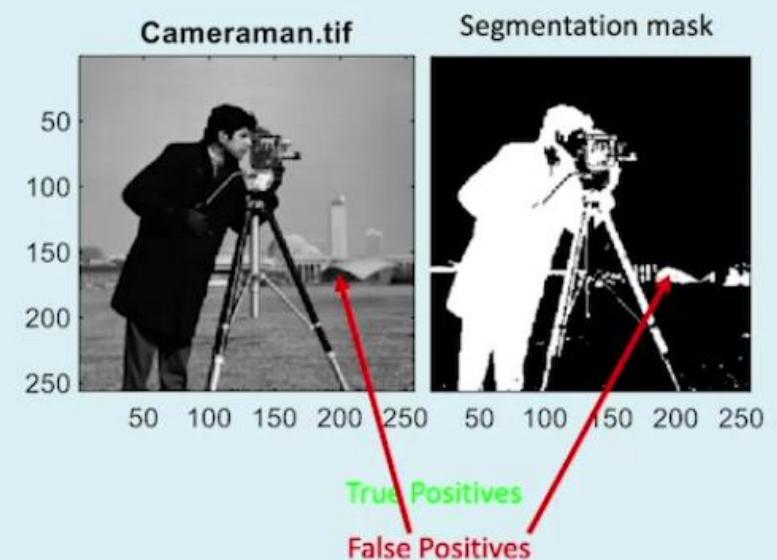
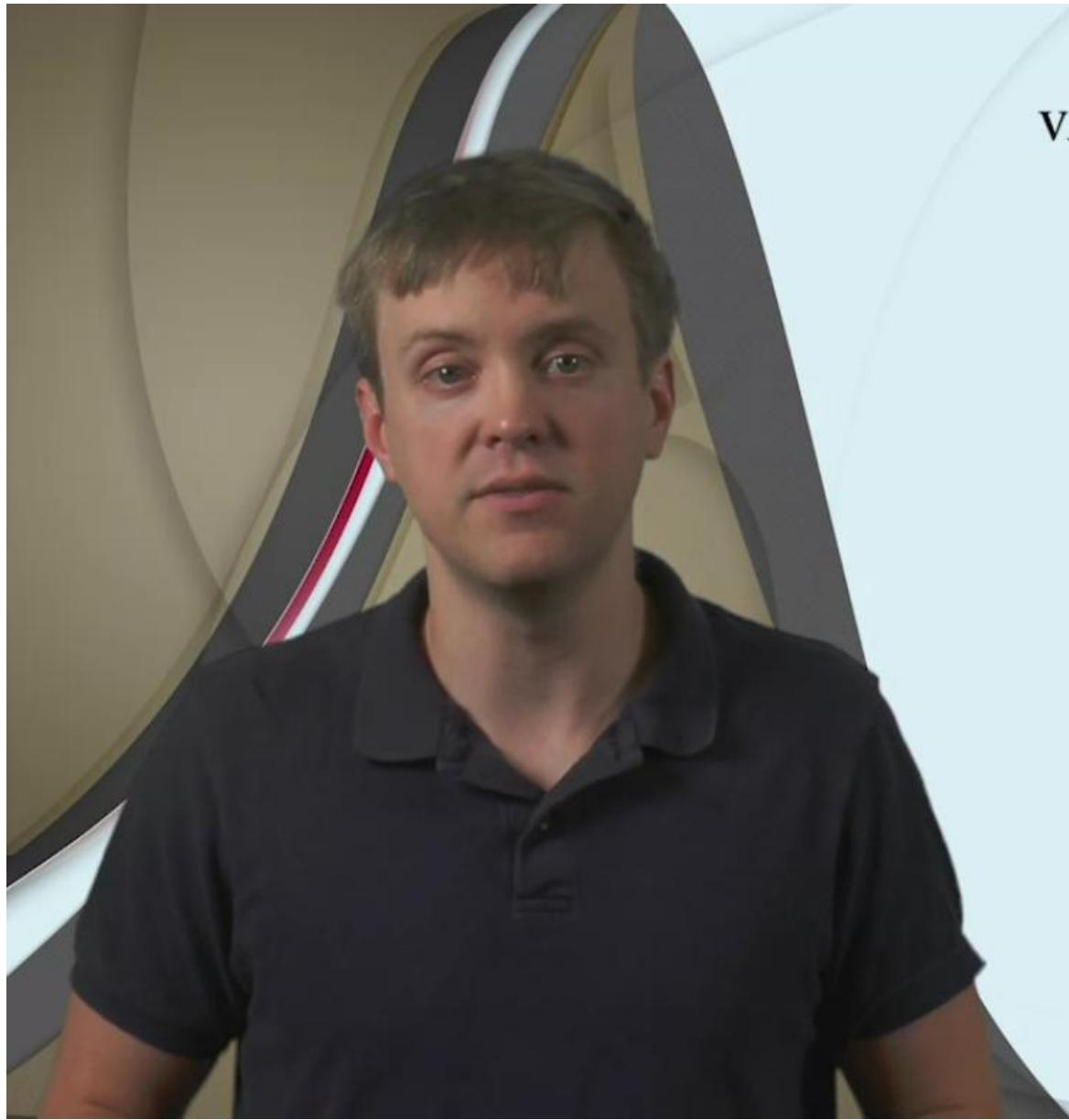
05:46 / 54:53
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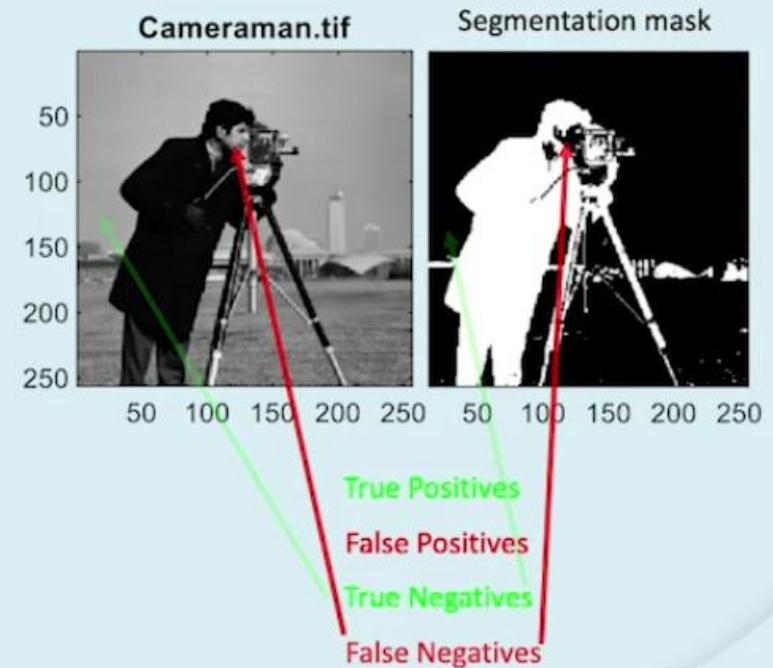


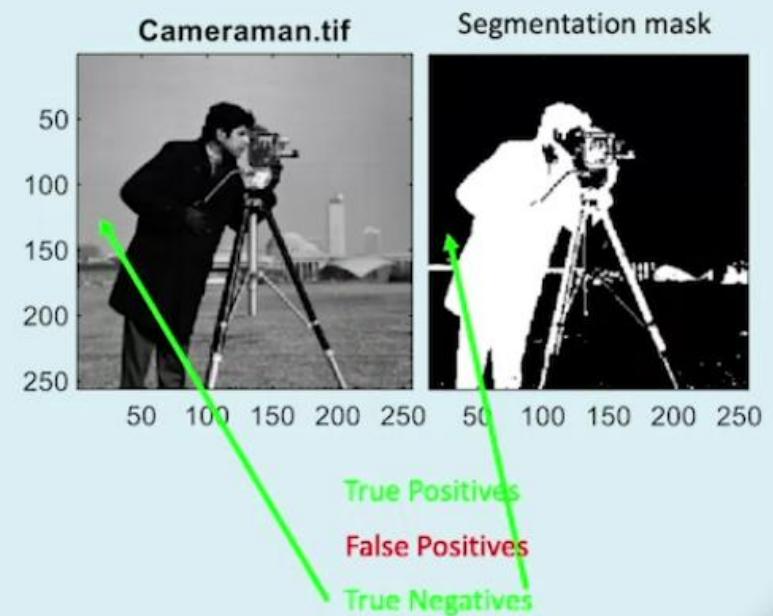
Introduction to Data, Signal, and Image Analysis with MATLAB®











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Name	Value	Size	Class
hst	256×1 double	256×1	double
img	256×256 uint8	256×256	uint8
thrsh	0.3451	1×1	double

COMMAND WINDOW

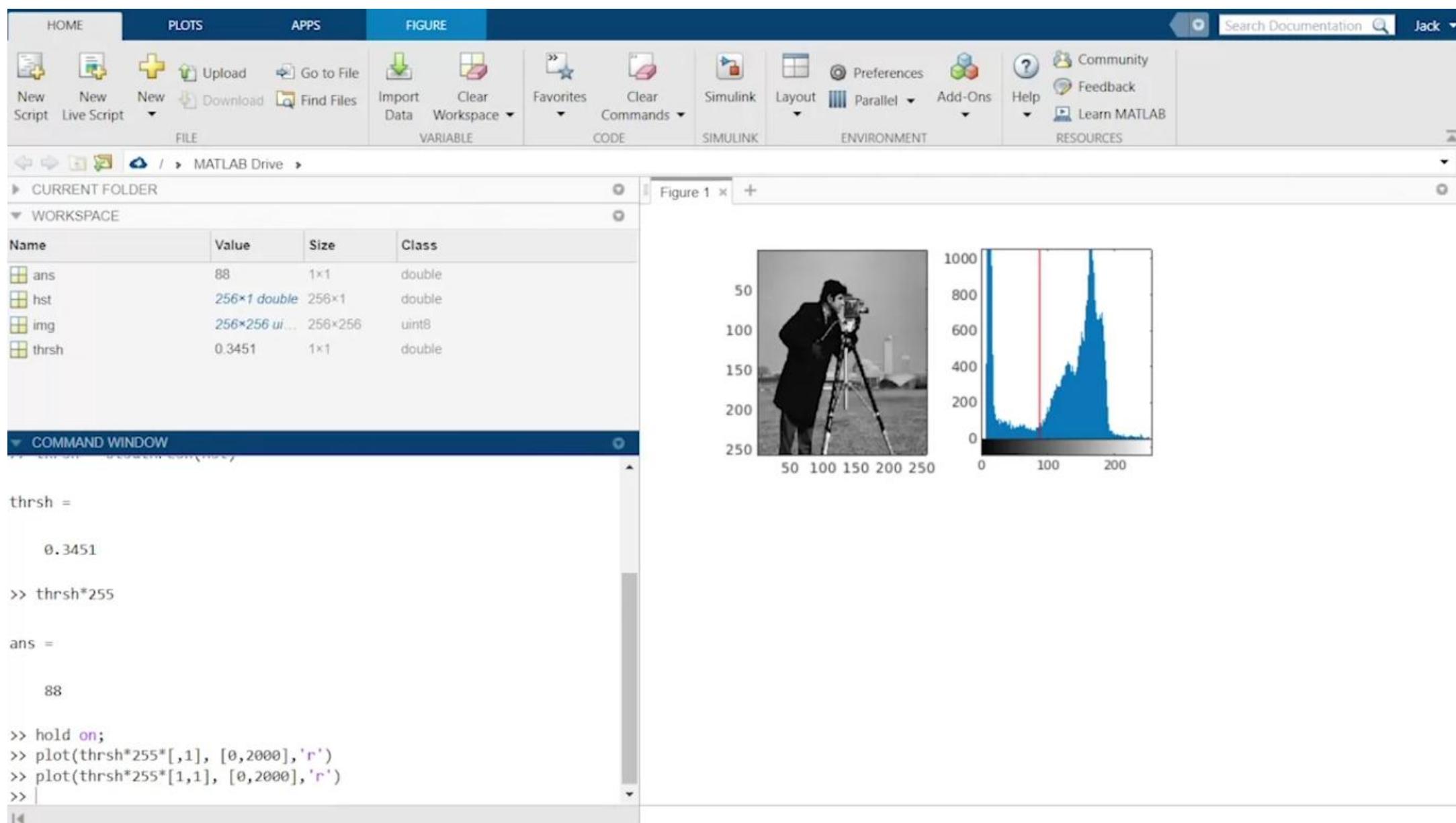
```
>> img = imread('cameraman.tif');
>> subplot(2,3,1)
>> image(img)
>> colormap(gray)
>> subplot(2,3,2)
>> imhist(img)
>> hst = imhist(img);
>> thrsh = otsuthresh(hst)
```

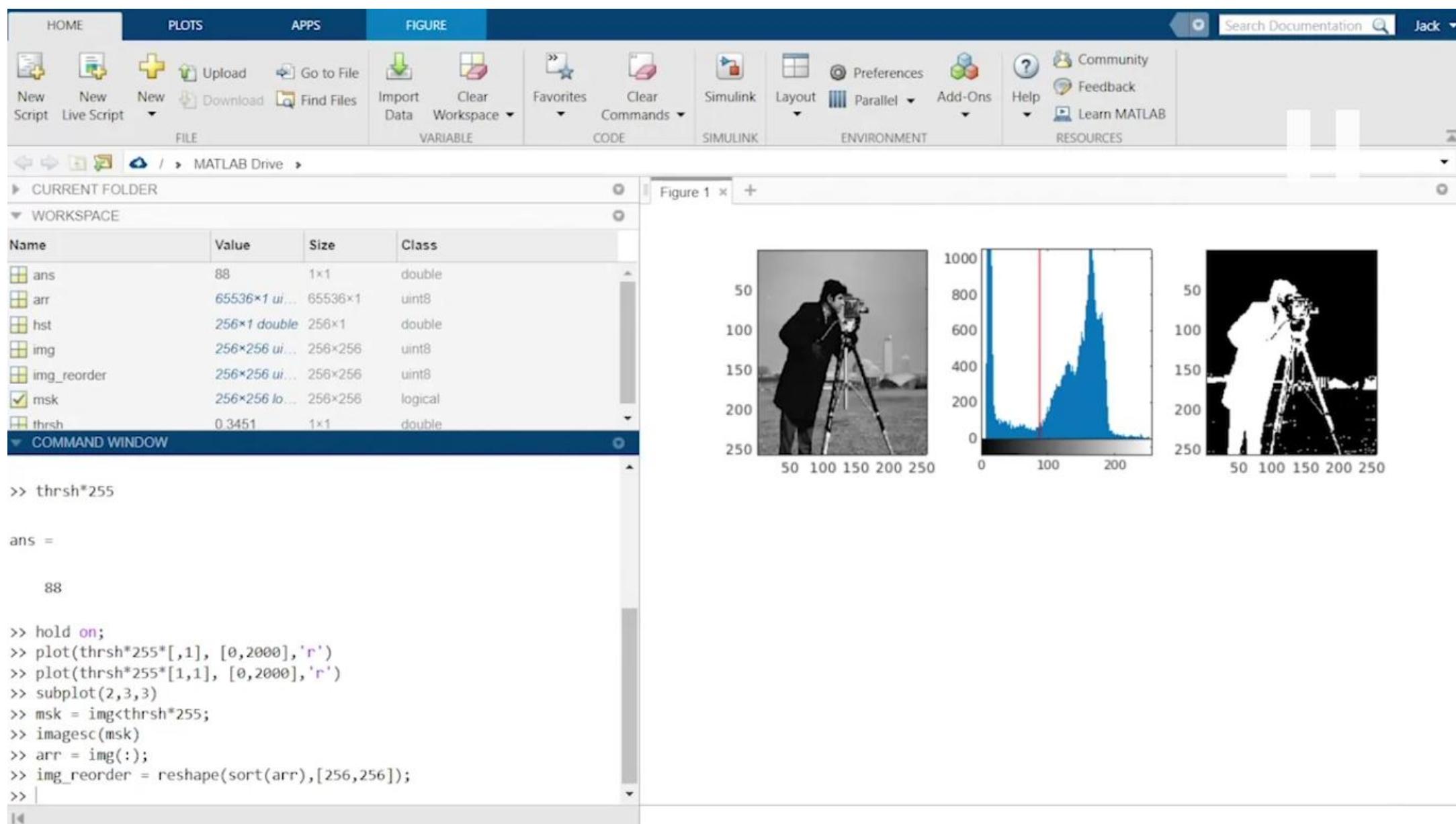
thrsh =

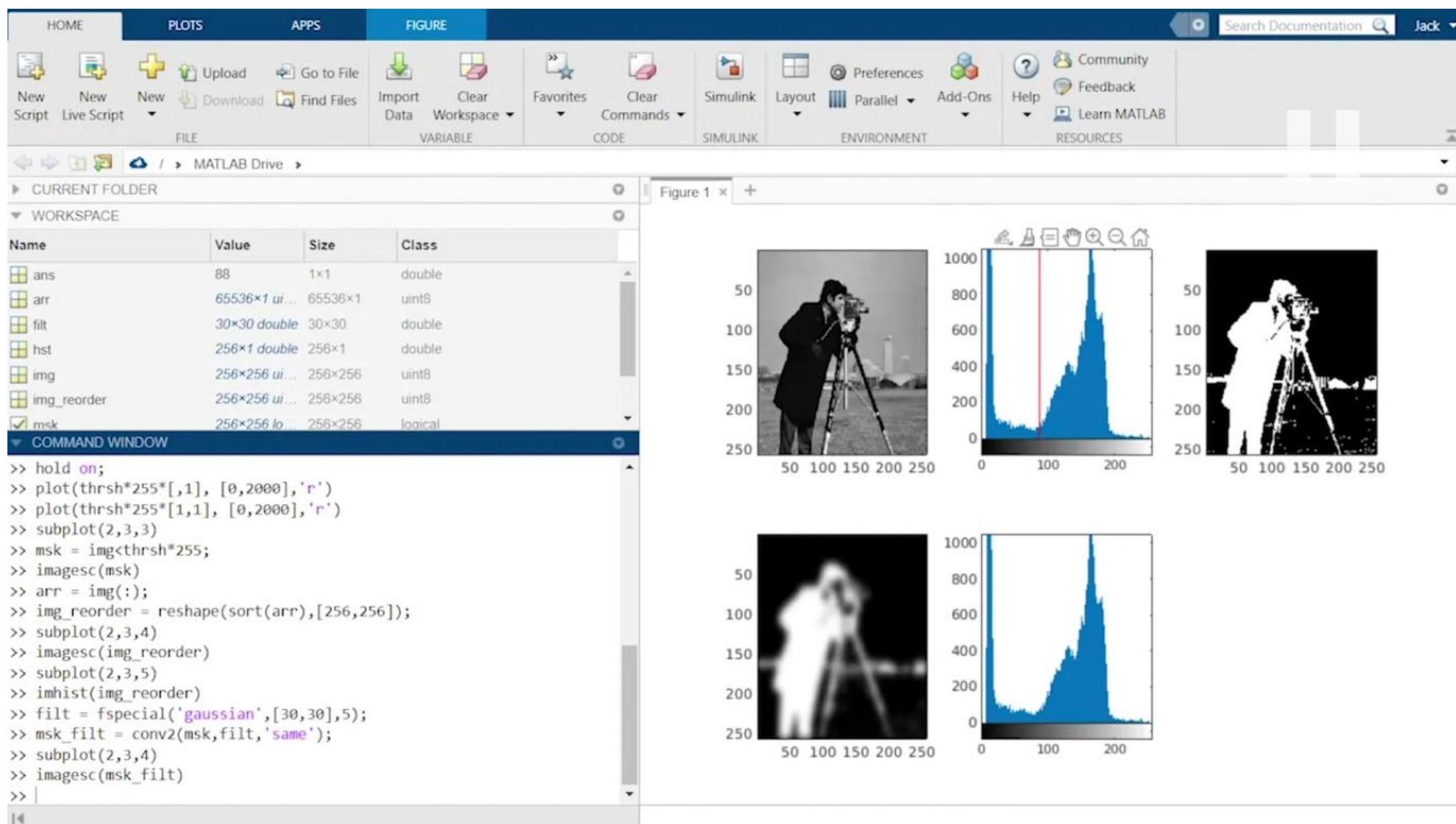
0.3451

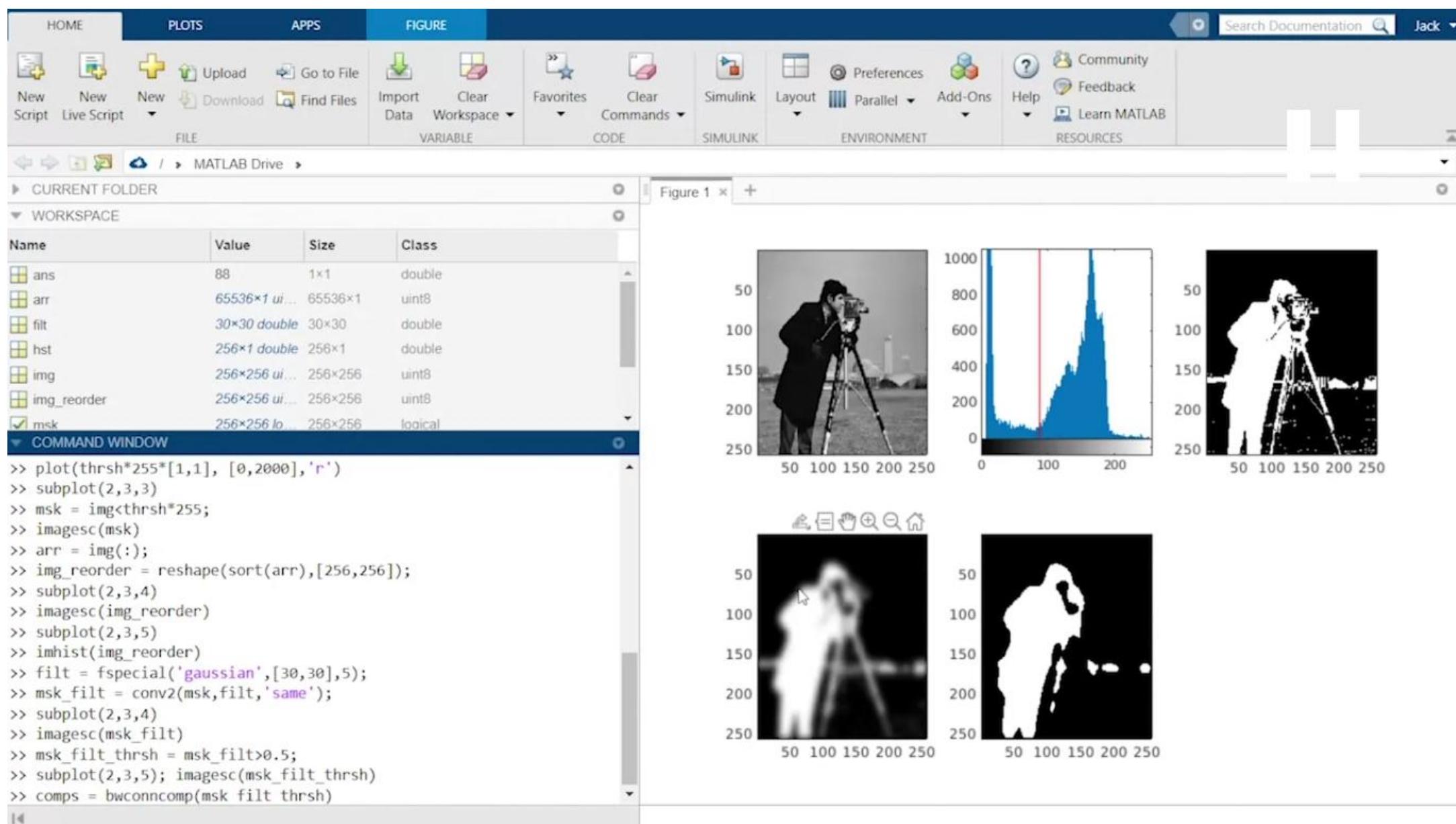
>> thres|

Figure 1 +









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FILE VARIABLE CODE SIMULINK ENVIRONMENT

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Name Value Size Class

ans	88	1x1	double
arr	65536x1 uint8	65536x1	uint8
comps	1x1 struct	1x1	struct
filt	30x30 double	30x30	double
hst	256x1 double	256x1	double
img	256x256 uint8	256x256	uint8
im_reorder	256x256 uint8	256x256	uint8

COMMAND WINDOW

```
>> MSK_filt_msh = MSK_filt>0.5,  
>> subplot(2,3,5); imagesc(msk_filt_thrsh)  
>> comps = bwconncomp(msk_filt_thrsh)
```

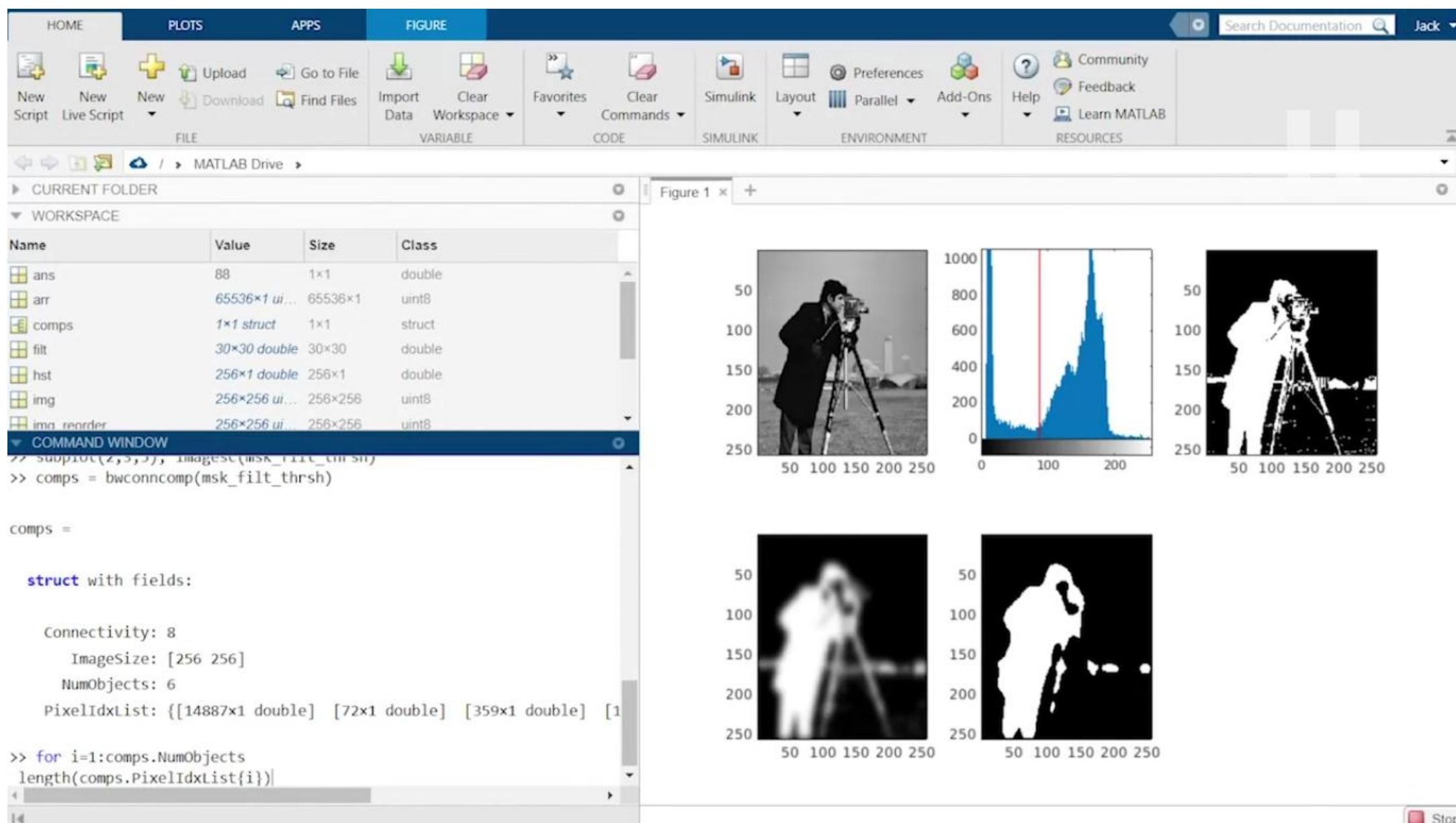
comps =

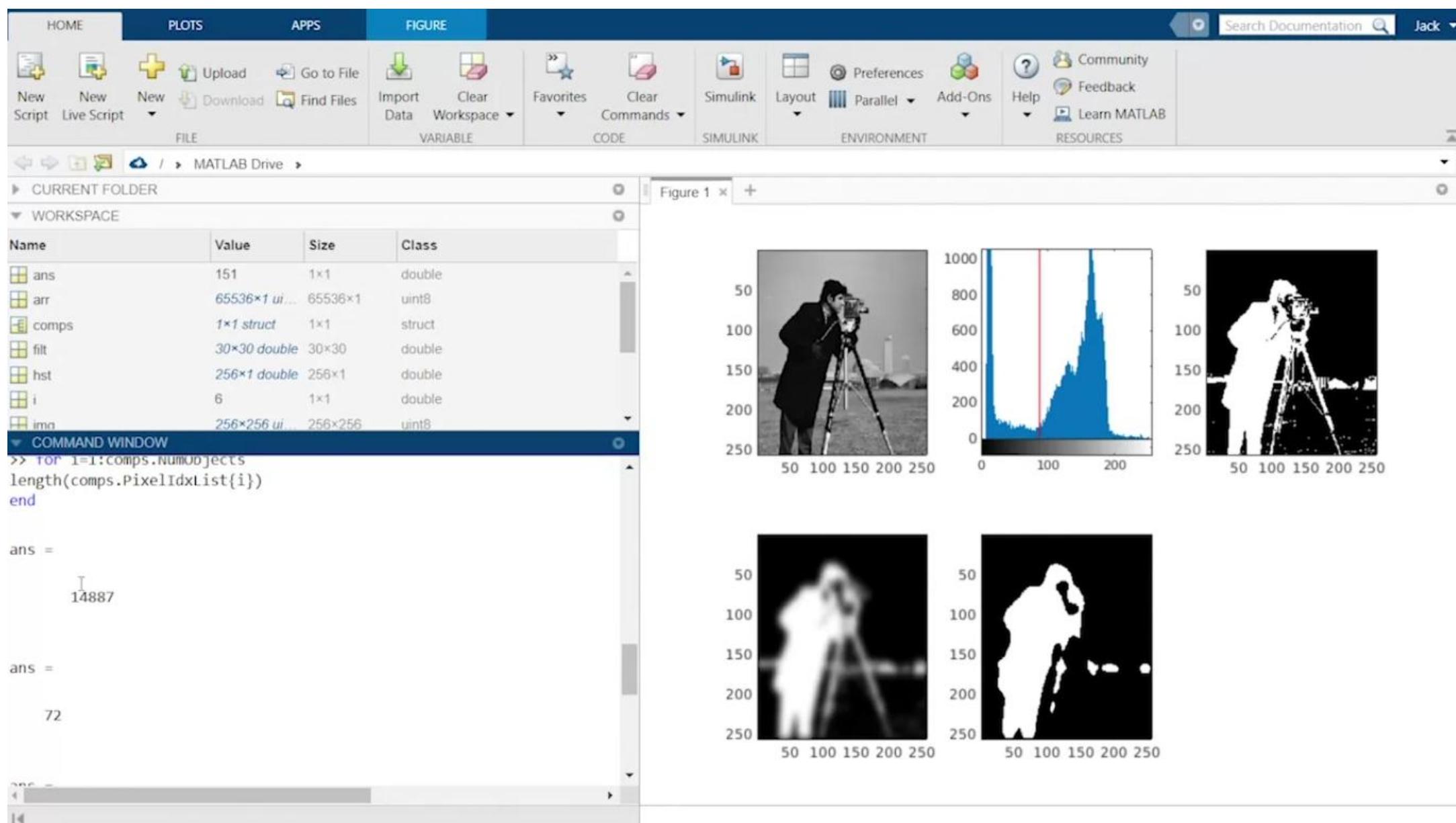
struct with fields:

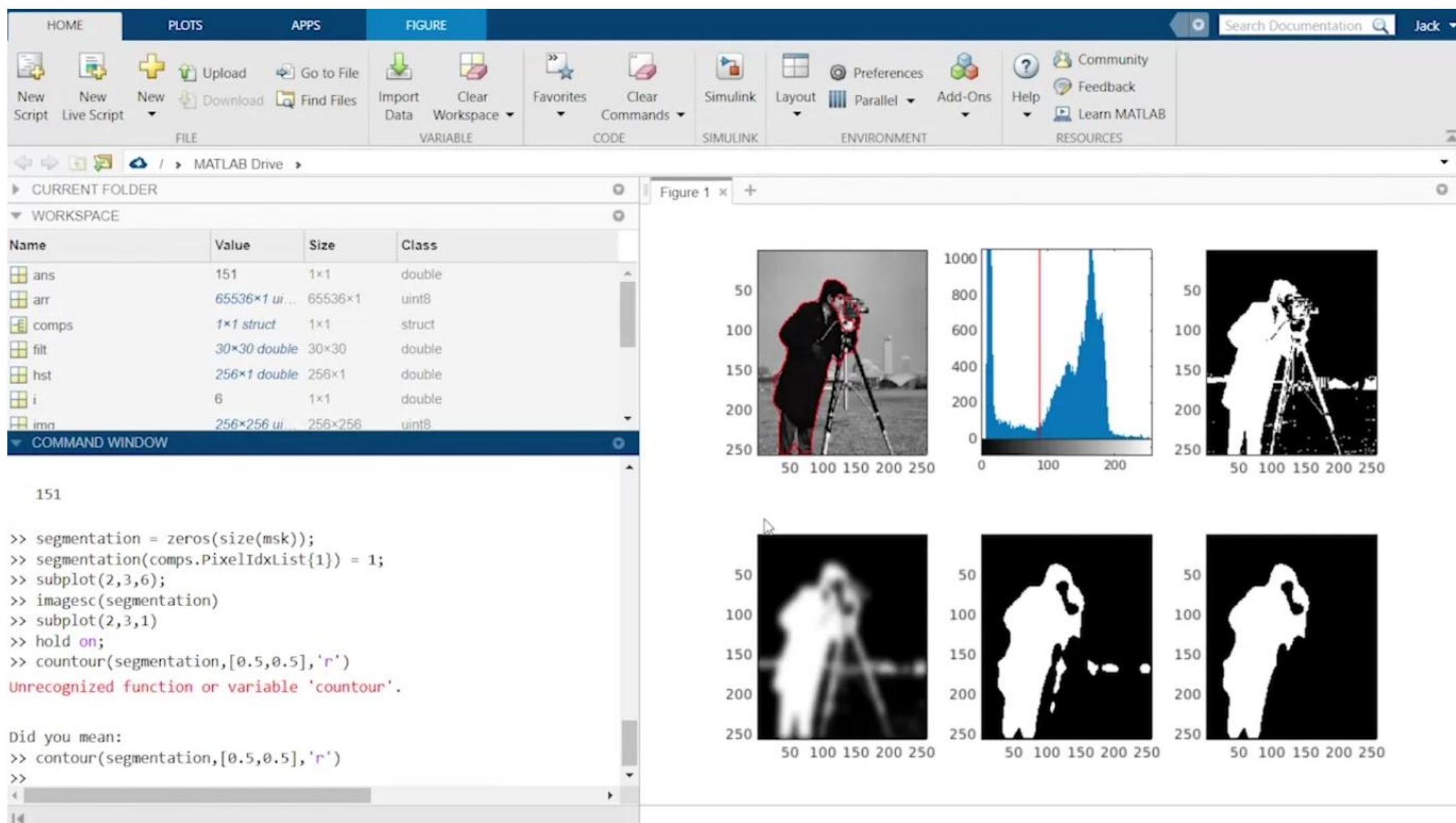
Connectivity: 8
ImageSize: [256 256]
NumObjects: 6
PixelIdxList: {[14887x1 double] [72x1 double] [359x1 double] [1 1]}

Figure 1 +

>> |







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FILE VARIABLE CODE SIMULINK ENVIRONMENT

MATLAB Drive > CURRENT FOLDER WORKSPACE

Name	Value	Size	Class
ans	151	1x1	double
arr	65536x1 ui...	65536x1	uint8
cmap	256x3 double	256x3	double
comps	1x1 struct	1x1	struct
filt	30x30 double	30x30	double
hst	256x1 double	256x1	double
hsy	384x512x3	384x512x3	double

COMMAND WINDOW

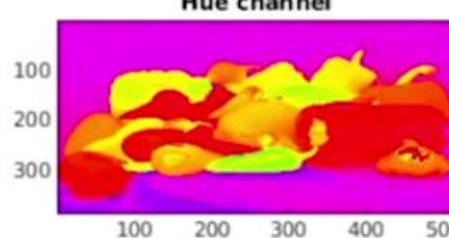
```
>> subplot(2,2,1)
>> hold on
>> countour(segmentation,[0.5,0.5],'r')
Unrecognized function or variable 'countour'.
```

Did you mean:

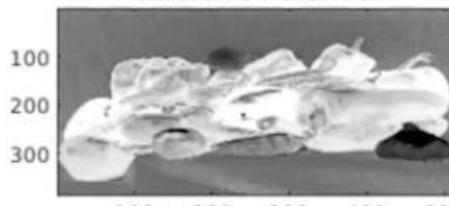
```
>> contour(segmentation,[0.5,0.5],'r')
>> img_canny = edge(img,'canny');
>> subplot(2,3,2)
>> imagesc(img_canny)
>> img = imread('peppers.png');
>> clf;
>> subplot(1,2,1); imagesc(img); axis tight equal
>> figure(2);
>> Lesson4_3_hsvfigure
>> |
```

Figure 1 X Figure 2 X +

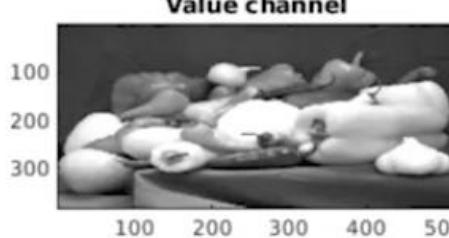
Hue channel



Saturation channel



Value channel



4000
3000
2000
1000
0

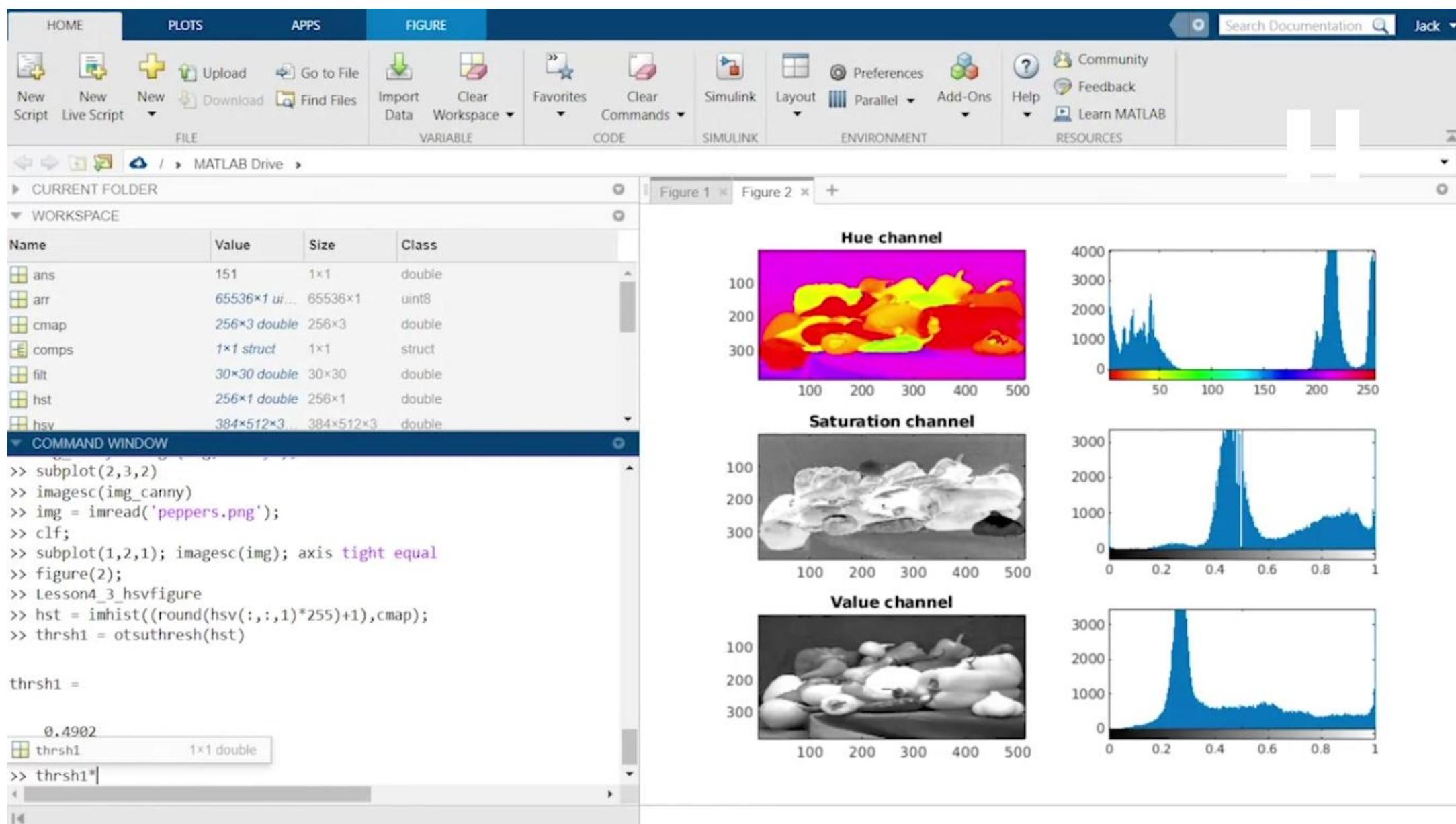
0 50 100 150 200 250

3000
2000
1000
0

0 0.2 0.4 0.6 0.8 1

3000
2000
1000
0

0 0.2 0.4 0.6 0.8 1



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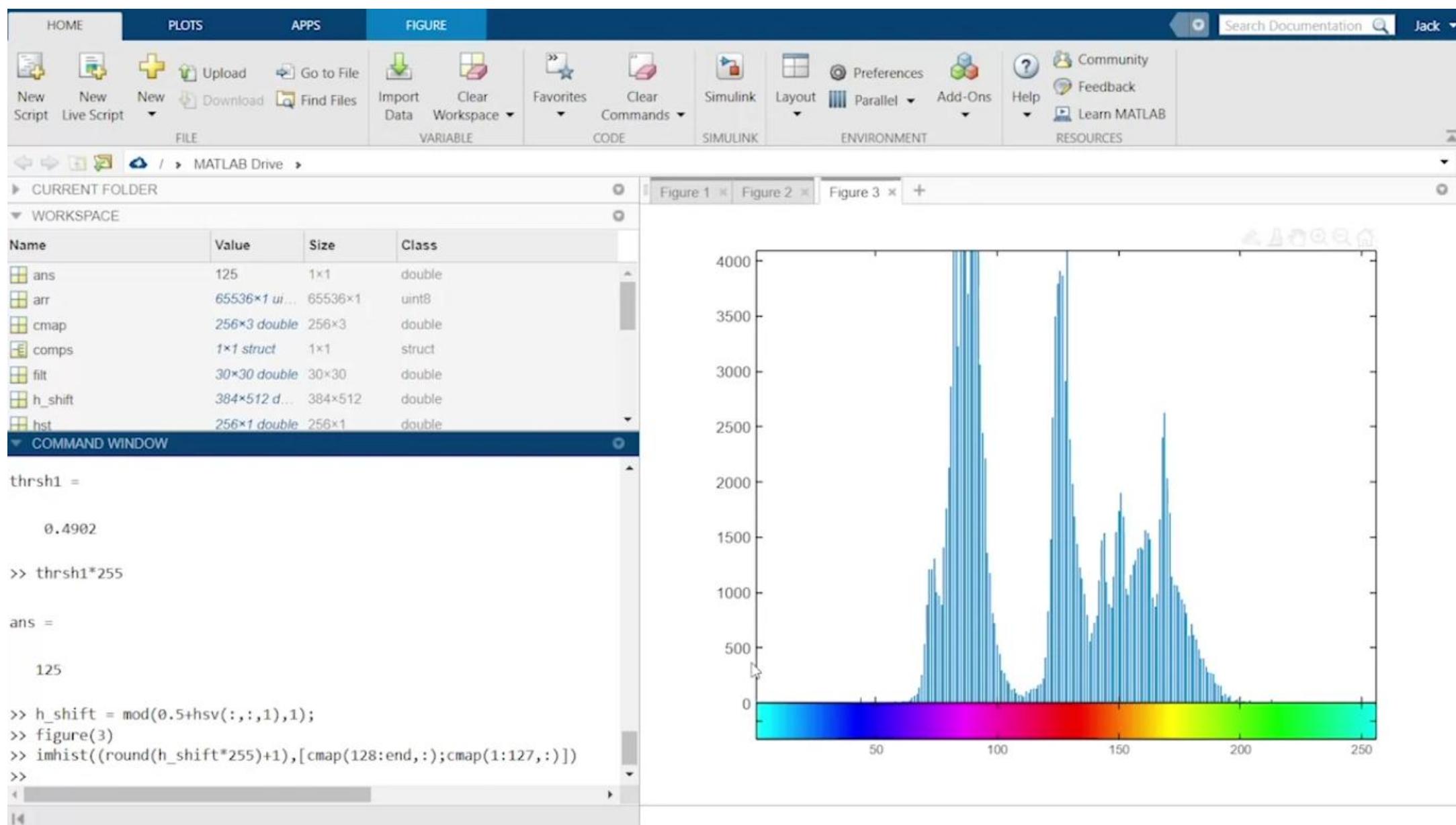
MATLAB Drive >

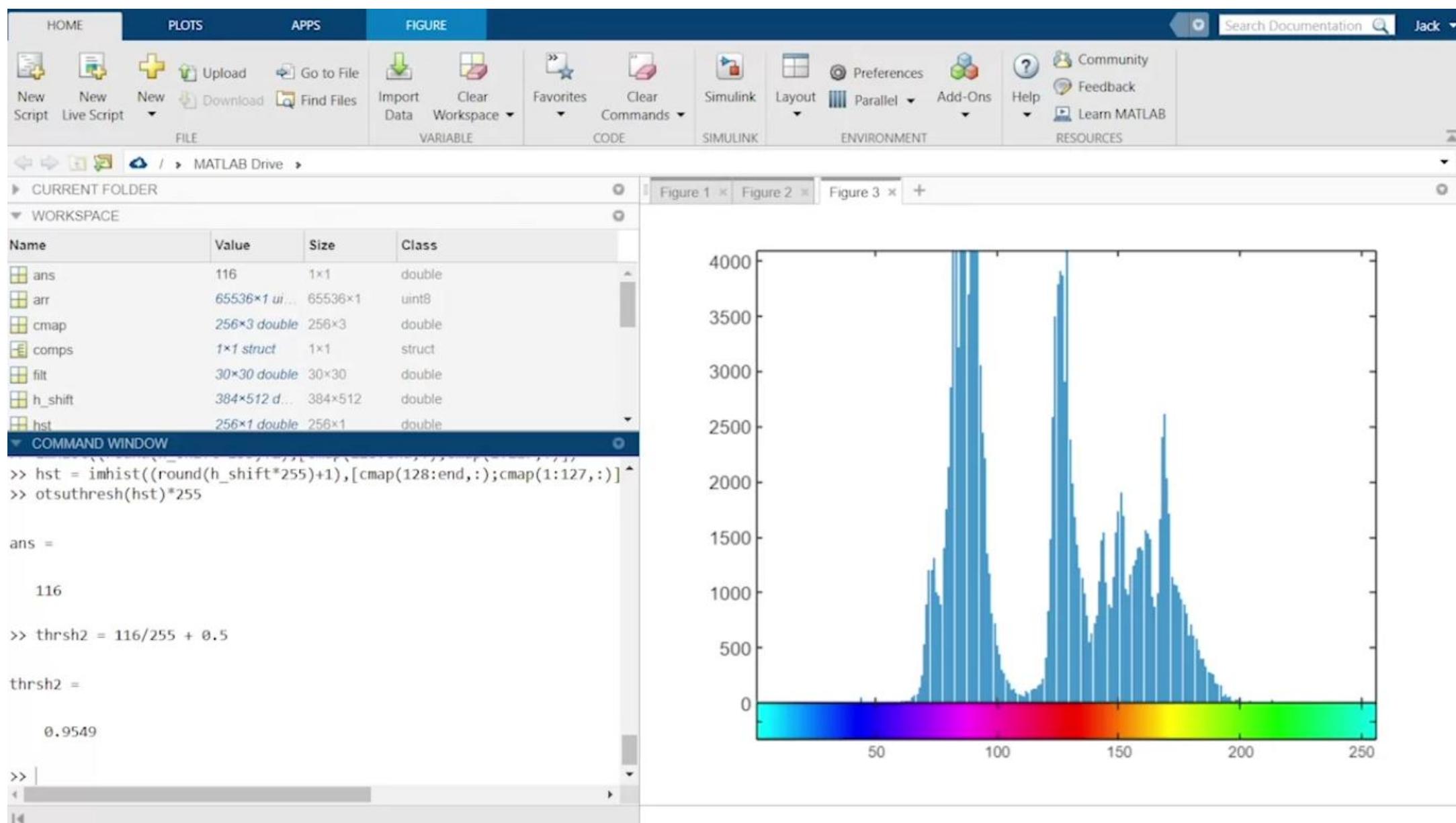
CURRENT FOLDER WORKSPACE

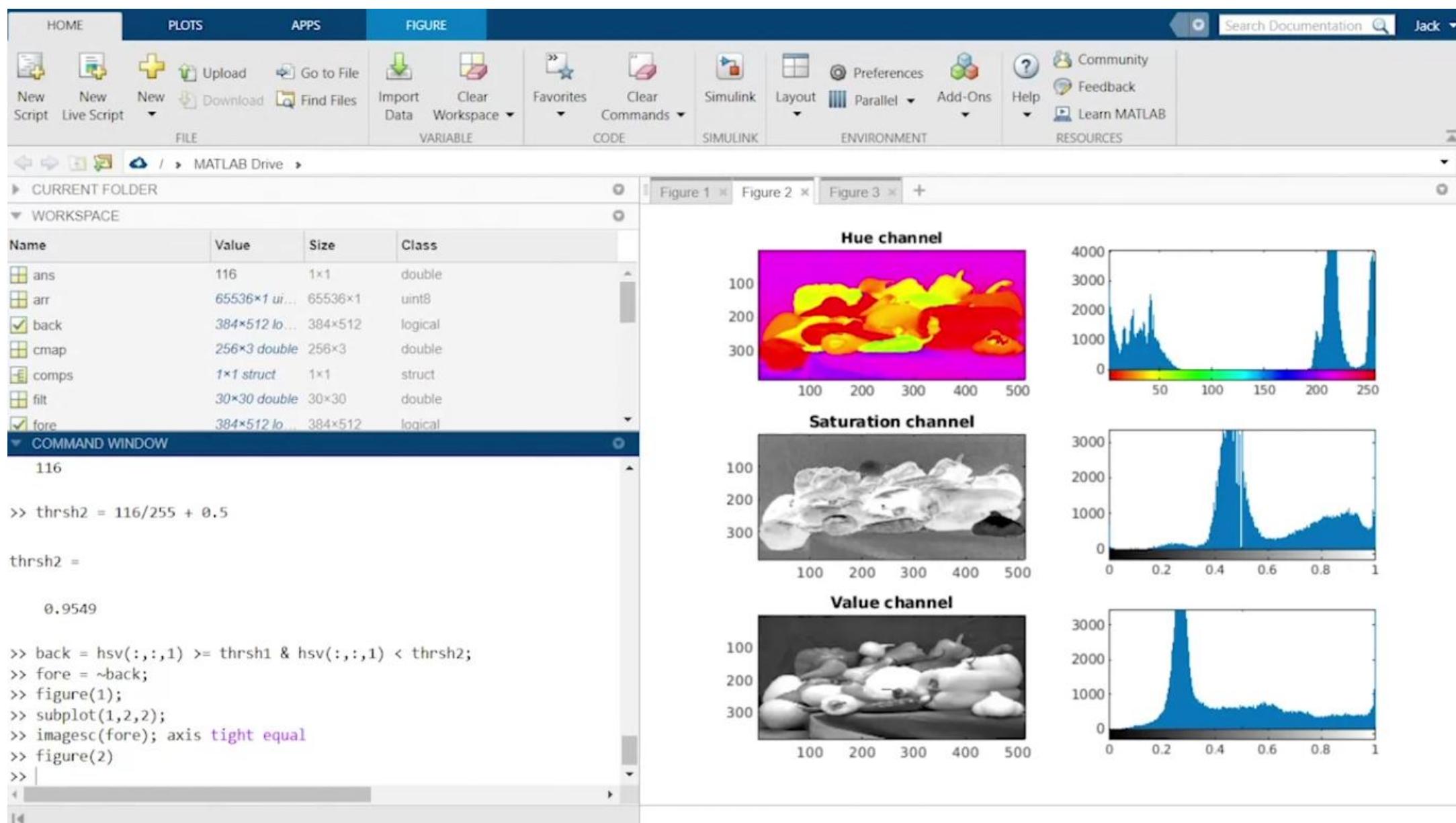
Name	Value	Size	Class
ans	125	1x1	double
arr	65536x1 ui...	65536x1	uint8
cmap	256x3 double	256x3	double
comps	1x1 struct	1x1	struct
filt	30x30 double	30x30	double
h_shift	384x512 d...	384x512	double
hst	256x1 double	256x1	double

COMMAND WINDOW

```
sh1 =
0.4902
thrsh1*255
;
125
h_shift = mod(0.5+ hsv(:,:,1),1);
figure(3)
imhist((round(h_shift*255)+1), [cmap(128:end,:);cmap(1:127,:)])
```







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FILE

Curve Fitting

Optimization

PID Tuner

Signal Analyzer

MATLAB Coder

Classification
LearnerDeep Network
DesignerExperiment
ManagerNeural Net
ClusteringNeural Net
FittingNeural Net
Pattern Recog...

APPS

Command Window

```
>> peppers = imread('peppers.png');
>> cameraman = imread('cameraman.tif');
```

fx >> |

Workspace

Name	Value
cameraman	256x256 uint8
peppers	384x512x3 uint8

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FILE



Command Window

```
>> peppers = imread('pep  
>> cameraman = imread('c
```

fx >>

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Color Thresholder - Choose a Color Space

THRESHOLD

Load Image New Color Space Invert Mask Reset Thresholds

Background Color:  Show Binary

Background Opacity:

Live Update

Background:  Hide Point Cloud

POINT-CLOUD

EXPORT

LOAD IMAGE COLOR SPACES MODIFY MASK

VIEW MASK LIVE UPDATE

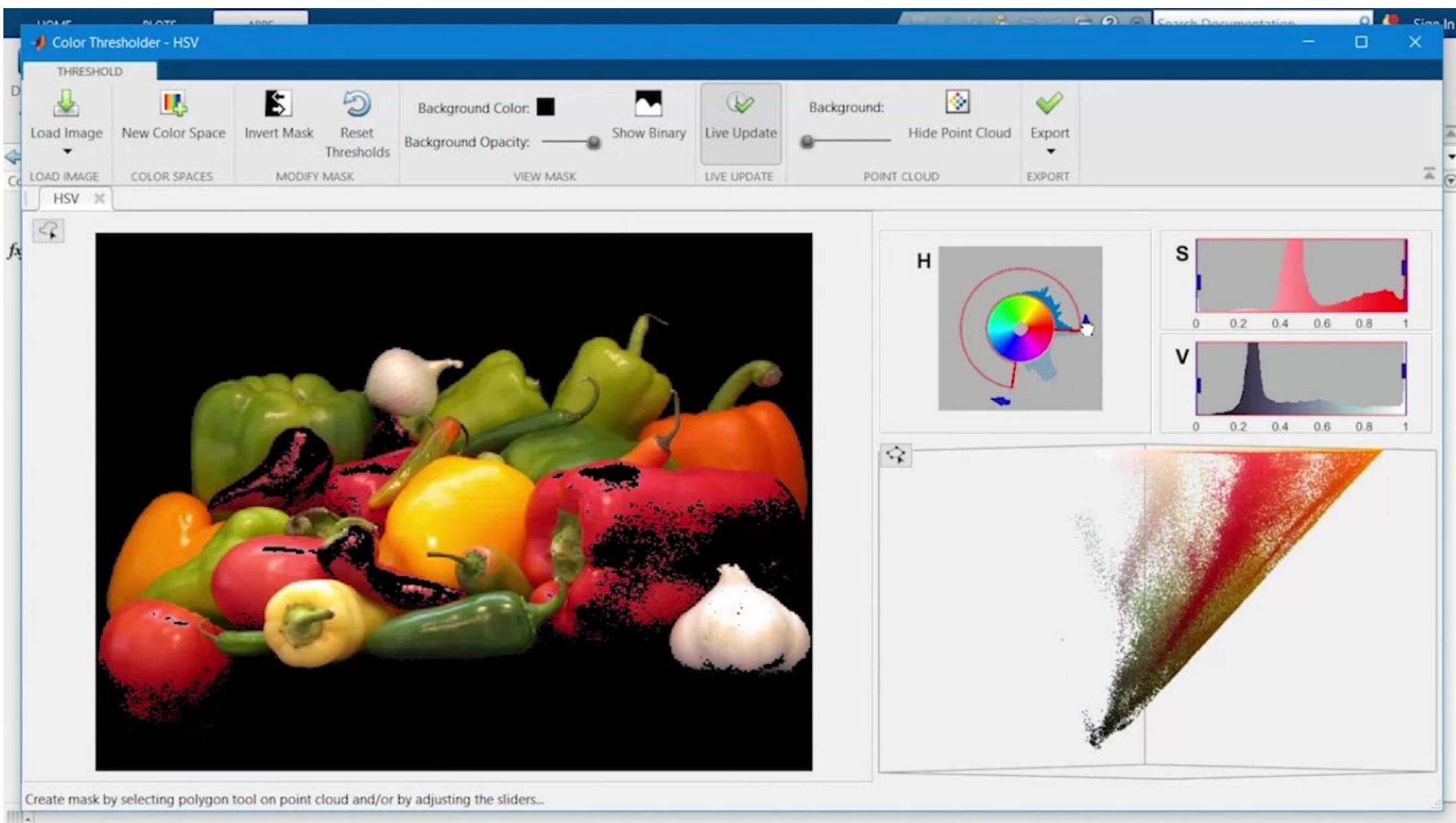
Choose a Color Space X

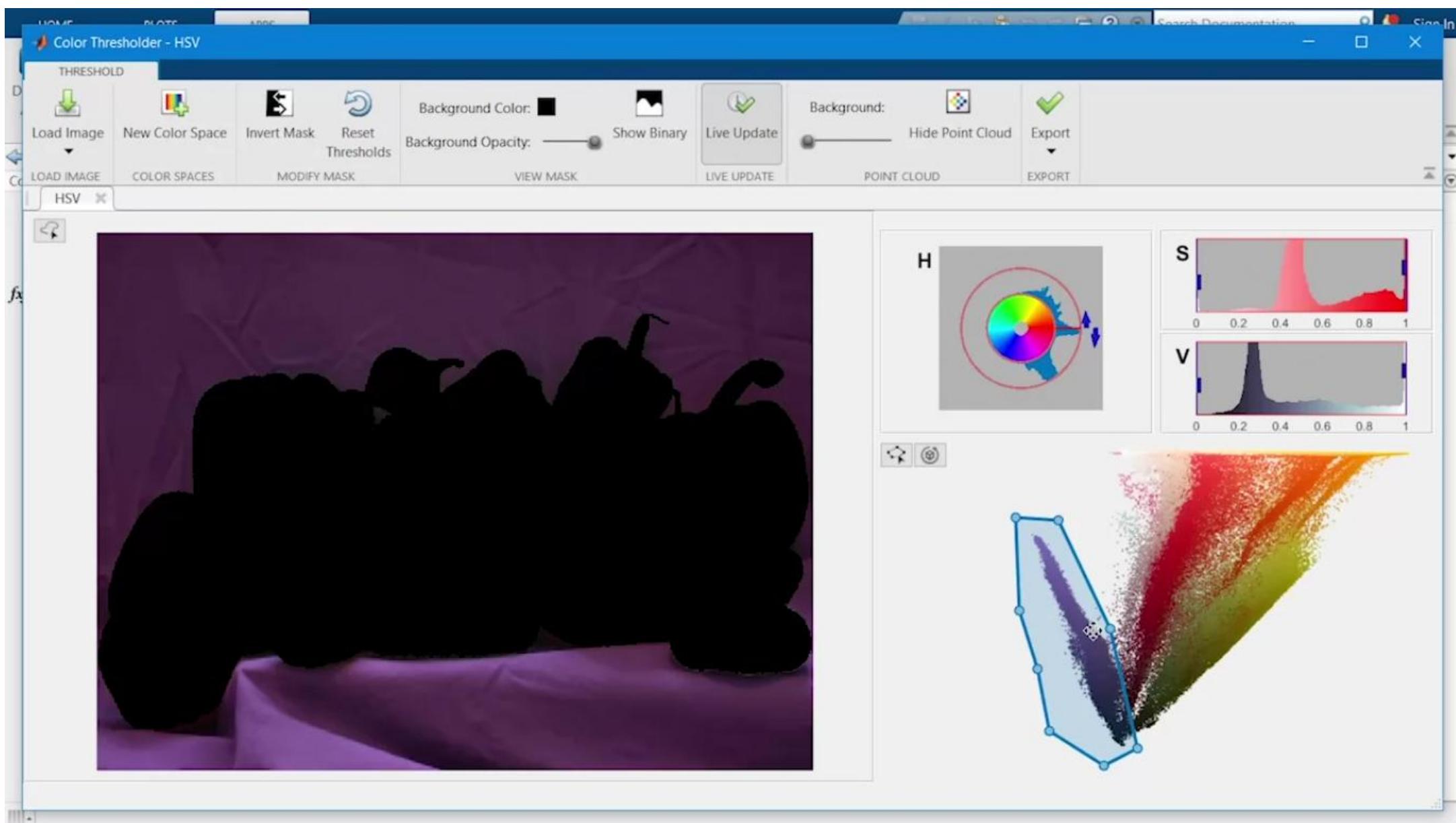
RGB HSV YCbCr L*a*b*

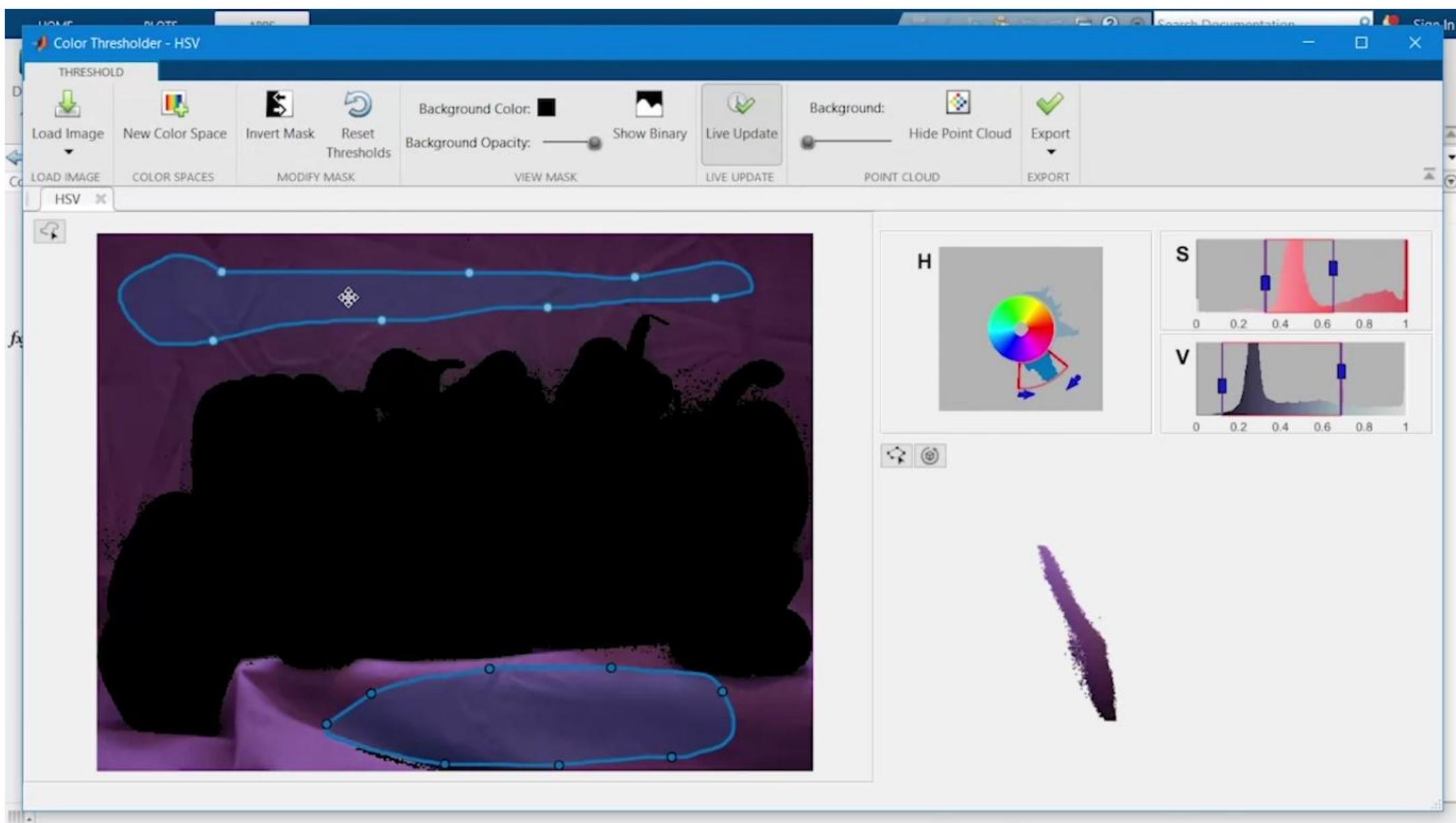
Az: 42 El: 0



Rotate the 3D color space and choose the view that best isolates the colors of interest...







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FILE

Command Window

```
>> peppers = imread('pep  
>> cameraman = imread('c  
1
```

fx >>

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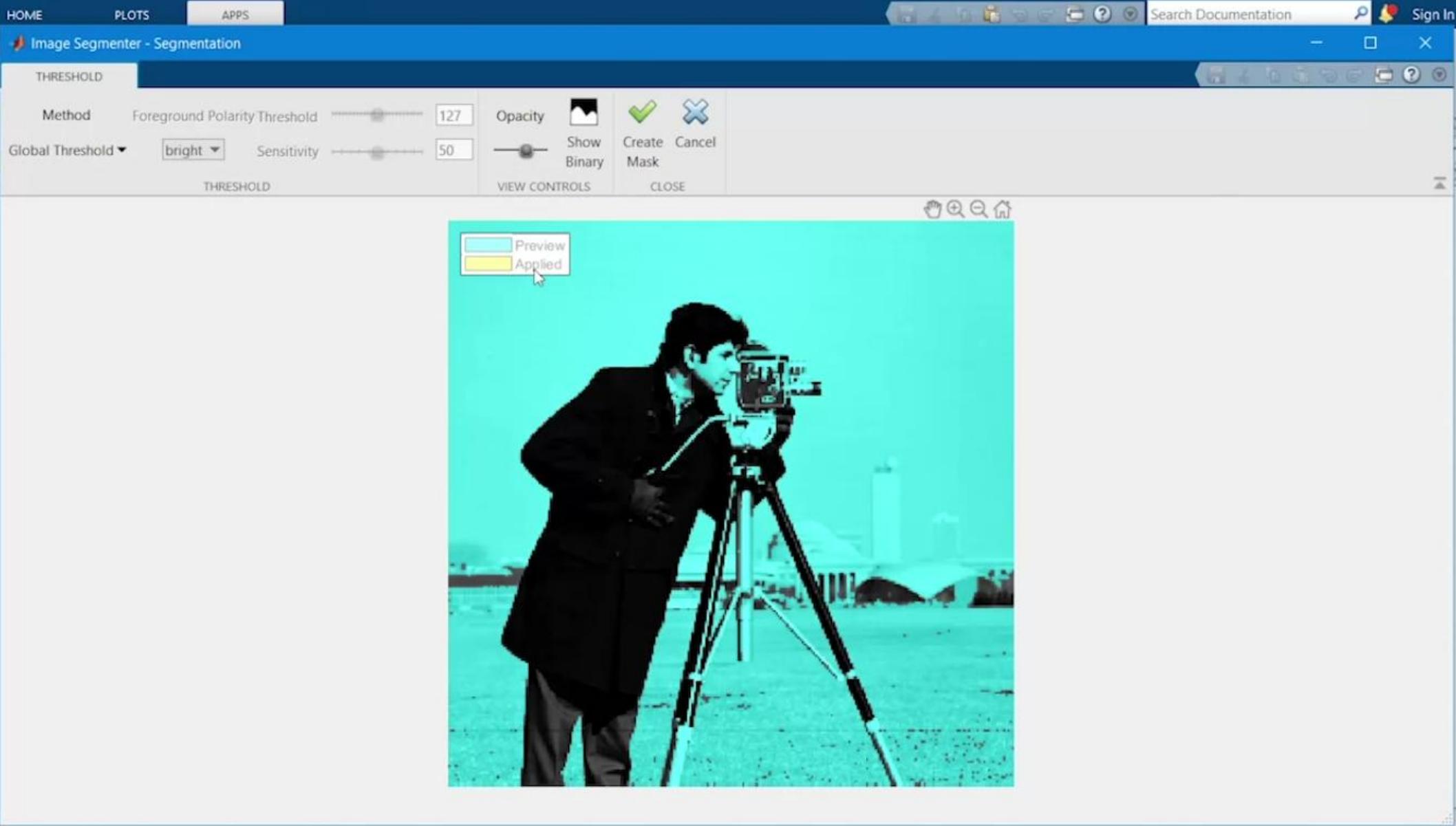
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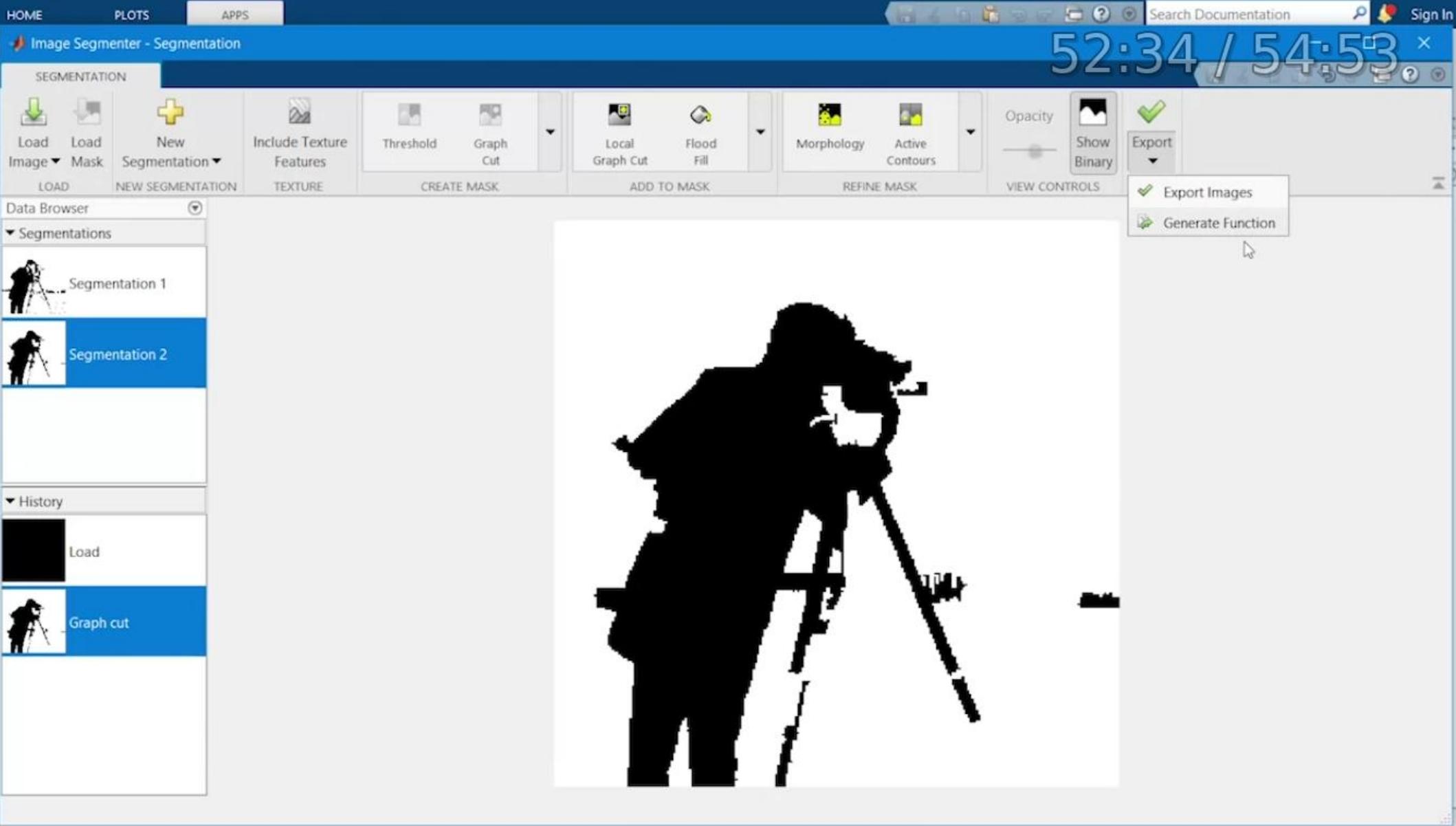
IMAGE PROCESSING AND COMPUTER VISION

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Genomics Viewer Molecule Viewer Phylogenetic Tree Sequence Alignment Sequence Viewer







VANDERBILT

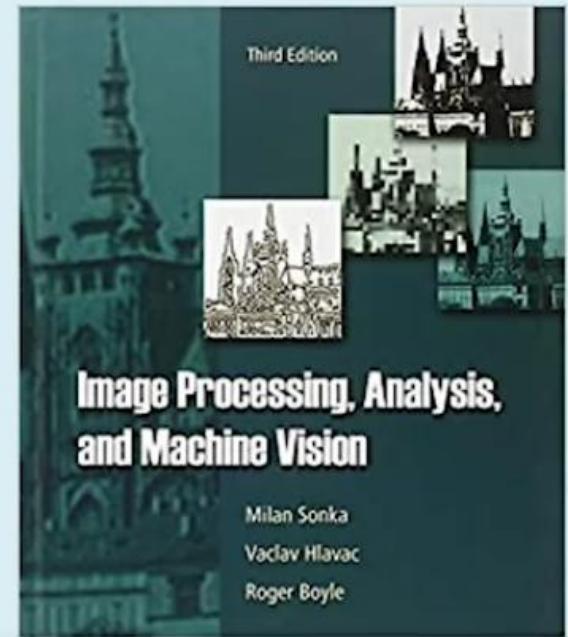
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Milan Sonka, Vaclav Hlavac, Roger Boyle

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Introduction to Data, Signal, and Image Analysis with MATLAB®