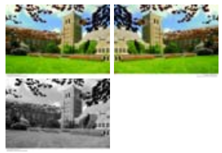
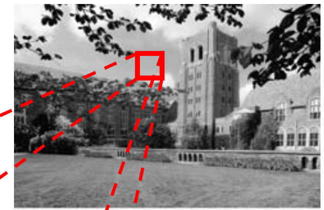
- Previous Lecture:
  - 2-d array examples
- Today's Lecture:
  - Image processing



- Announcements:
  - Prelim 2 tonight 7:30-9pm
  - Project 4 will be posted tonight. Due Monday Oct 27th

A picture as a matrix

1458-by-2084



150	149	152	153	152	155
151	150	153	154	153	156
153	151	155	156	155	158
154	153	156	157	156	159
156	154	158	159	158	161
157	156	159	160	159	162

Images can be encoded in different ways

- Common formats include
  - JPEG: Joint Photographic Experts Group
  - GIF: Graphics Interchange Format
- Data are compressed
- We will work with jpeg files:
  - **imread**: read a .jpg file and convert it to a "normal numeric" array that we can work with
  - **imwrite**: write an array into a .jpg file (compressed data)

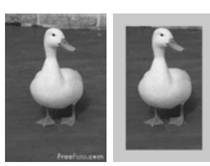
Grayness: a value in [0..255]

0 = black
255 = white

These are *integer* values
Type: `uint8`

150	149	152	153	152	155
151	150	153	154	153	156
153	151	155	156	155	158
154	153	156	157	156	159
156	154	158	159	158	161
157	156	159	160	159	162

Let's put a picture in a frame



Things to do:

1. Read `bwduck.jpg` from memory and convert it into an array
2. Show the original picture
3. Assign a gray value (frame color) to the "edge pixels"
4. Show the manipulated picture

Reading a jpeg file and displaying the image

```
% Read jpg image and convert to
% an array P
  P = imread('bwduck.jpg');

% Show the data in array P as
% an image
  imshow(P)
```

```
% Frame a grayscale picture

P= imread('bwduck.jpg');
imshow(P)

% Change the "frame" color
width= 50;
frameColor= 200;  % light gray
[nr,nc]= size(P);
for r= 1:nr
  for c= 1:nc
    % At pixel (r,c)



  end
end
imshow(P)
```



```
% Frame a grayscale picture

P= imread('bwduck.jpg');
imshow(P)

% Change the "frame" color
width= 50;
frameColor= 200;  % light gray
[nr,nc]= size(P);
for r= 1:nr
  for c= 1:nc
    % At pixel (r,c)
    if  r<=width || r>nr-width || ...
        c<=width || c>nc-width
      P(r,c)= frameColor;
    end
  end
end
imshow(P)
```

Things to consider…
1. What is the type of the values in P?
2. Can we be more efficient?

See `pictureFrame*.m`

Accessing a submatrix

M

2	-1	.5	0	-3
3	8	6	7	7
5	-3	8.5	9	10
52	81	.5	7	2

- `M` refers to the whole matrix
- `M(3,5)` refers to one component of `M`
- `M(2:3,3:5)` refers to a submatrix of `M`

row indices

column indices

A color picture is made up of RGB matrices → 3-d array

114	114	112	112	114	111	114	115	112	113
114	113	111	109	113	111	113	115	112	113
115	114	112	111	111	112	112	111	112	112
116	117	116	114	112	115	113	112	115	114
113	112	112	112	112	110	111	113	116	115
115	115	115	115	113	111	111	113	116	114
112	113	116	117	113	112	112	113	114	113
115	116	118	118	113	112	112	113	114	114
116	116	117	117	114	114	112	112	114	115

153	153	150	150	154	151	152	153	150	151
153	152	149	147	153	151	151	153	150	151
154	153	151	150	151	152	150	149	150	150
155	156	155	152	152	155	151	150	153	153
151	150	150	150	150	148	149	151	152	151
153	153	153	153	151	149	149	151	152	150
150	151	152	153	151	150	150	151	152	151
153	154	154	154	151	150	150	151	152	152
154	154	153	153	149	149	150	150	152	153

212	212	212	212	216	213	215	216	213	213
212	211	211	209	215	213	214	216	213	213
213	212	210	209	212	214	213	212	213	212
214	215	214	214	213	216	214	213	215	212
213	212	212	212	212	210	211	213	214	211
215	215	216	216	213	211	211	213	212	210
212	213	214	215	213	212	212	213	214	213
215	216	216	216	213	212	212	213	214	214
216	216	215	215	213	213	213	213	214	215

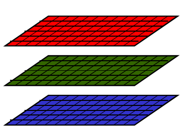
E.g., color image data is stored in a 3-d array **A**:

0 ≤ `A(i,j,1)` ≤ 255
0 ≤ `A(i,j,2)` ≤ 255
0 ≤ `A(i,j,3)` ≤ 255

A color picture is made up of RGB matrices → 3-d array

Color image

3-d Array



0 ≤ `A(i,j,1)` ≤ 255
0 ≤ `A(i,j,2)` ≤ 255
0 ≤ `A(i,j,3)` ≤ 255

Operations on images amount to operations on matrices!

Example: Mirror Image

`LawSchool.jpg`

`LawSchoolMirror.jpg`

1. Read **LawSchool.jpg** from memory and convert it into an array.
2. Manipulate the Array.
3. Convert the array to a jpg file and write it to memory.

Reading and writing jpg files

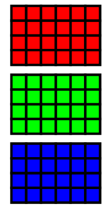
```
% Read jpg image and convert to
% a 3D array A
  A = imread('LawSchool.jpg');

% Write 3D array B to memory as
% a jpg image
  imwrite(B,'LawSchoolMirror.jpg')
```


A 3-d array as 3 matrices

```
[nr, nc, np] = size(A)  % dimensions of 3-d array A
```

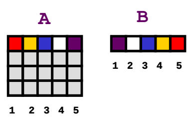
#rows #columns #layers (pages)

`A(1:nr,1:nc,1)`



	4-by-6	`M1= A(:,:,1)`
	4-by-6	`M2= A(:,:,2)`
	4-by-6	`M3= A(:,:,3)`


```
%Store mirror image of A in array B

[nr,nc,np]= size(A);
for r= 1:nr
  for c= 1:nc

     B(r,c  )= A(r,nc-c+1  );

  end
end
```




```
[nr,nc,np]= size(A);
for r= 1:nr
  for c= 1:nc
    for p= 1:np
      B(r,c,p)= A(r,nc-c+1,p);
    end
  end
end
```

This is non-vectorized code.

```
[nr,nc,np]= size(A);
for p= 1:np
  for r= 1:nr
    for c= 1:nc
      B(r,c,p)= A(r,nc-c+1,p);
    end
  end
end
```

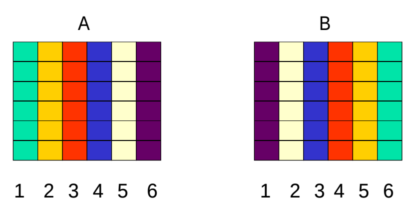
Both fragments create a mirror image of **A** .

A true

B false


```
% Make mirror image of A -- the whole thing

A= imread('LawSchool.jpg');
[nr,nc,np]= size(A);

B= zeros(nr,nc,np);
B= uint8(B);  % Type for image color values

for r= 1:nr
  for c= 1:nc
    for p= 1:np
      B(r,c,p)= A(r,nc-c+1,p);
    end
  end
end
imshow(B)  % Show 3-d array data as an image
imwrite(B,'LawSchoolMirror.jpg')
```


Vectorized code simplifies things…
Work with a whole column at a time



Column c in B
is column nc-c+1 in A

Vectorized code to create a mirror image

```
A = imread('LawSchool.jpg')
[nr,nc,np] = size(A);
for c= 1:nc
    B(:,c,1) = A(:,nc-c+1,1)
    B(:,c,2) = A(:,nc-c+1,2)
    B(:,c,3) = A(:,nc-c+1,3)
end
imwrite(B,'LawSchoolMirror.jpg')
```


Even more compact vectorized code to create a mirror image…

```
for c= 1:nc
    B(:,c,1) = A(:,nc-c+1,1)
    B(:,c,2) = A(:,nc-c+1,2)
    B(:,c,3) = A(:,nc-c+1,3)
end
```

```
B = A(:,nc:-1:1,:)
```


Vectorized code to create a mirror image

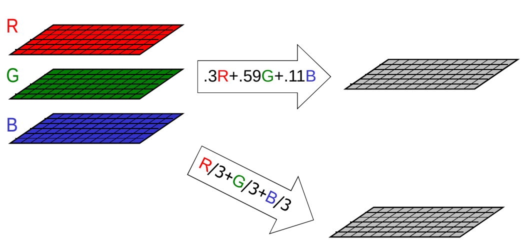
```
A = imread('LawSchool.jpg')
[nr,nc,np] = size(A);
for c= 1:nc
    B(:,c,1) = A(:,nc+1-c,1)
    B(:,c,2) = A(:,nc+1-c,2)
    B(:,c,3) = A(:,nc+1-c,3)
end
imwrite(B,'LawS ... jpg')
```

Can improve efficiency by initializing B to be a 3-d array of the appropriate size

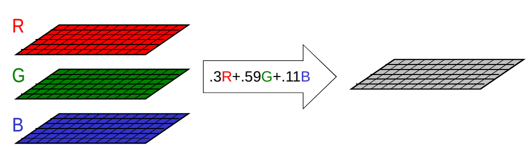
Example: color → black and white

Can "average" the three color values to get one gray value.

Averaging the RGB values to get a gray value



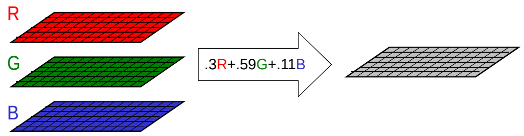
Averaging the RGB values to get a gray value




```
for  i= 1:m
   for j= 1:n
      M(i,j)= .3*R(i,j) + .59*G(i,j) + .11*B(i,j)
   end
end
```

scalar operation

Averaging the RGB values to get a gray value



M= .3*R + .59*G + .11*B

vectorized operation

Here are 2 ways to calculate the average. Are gray value matrices g and h the same given image data A?

```
for r= 1:nr
  for c= 1:nc
    g(r,c)= A(r,c,1)/3 + A(r,c,2)/3 + ...
            A(r,c,3)/3;
    h(r,c)= ...
         ( A(r,c,1)+A(r,c,2)+A(r,c,3) )/3;
  end
end
```

A: yes

B: no

showToGrayscale.m

Matlab has a built-in function to convert from color to grayscale, resulting in a 2-d array:

B = rgb2gray(A)