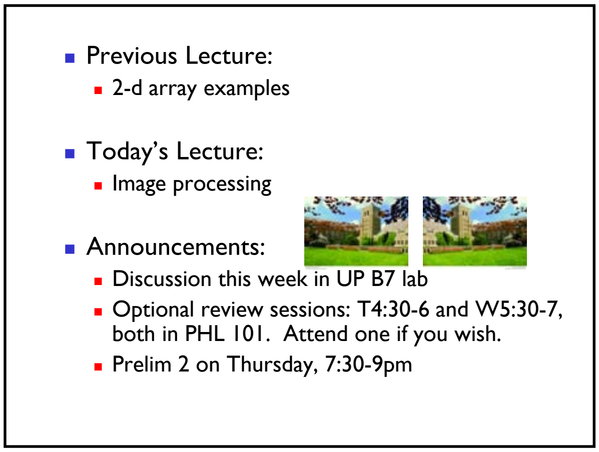
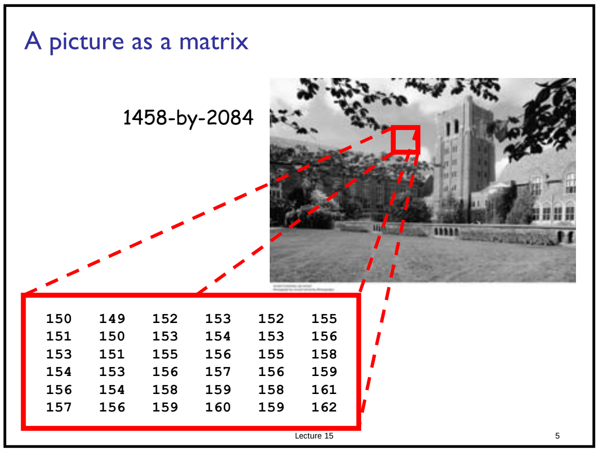


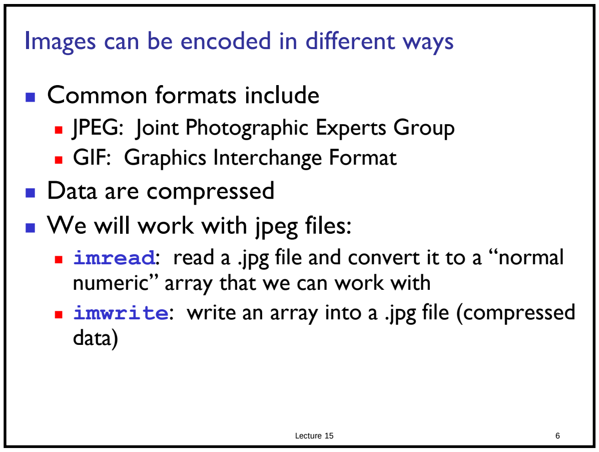
- Previous Lecture:
  - 2-d array examples
- Today's Lecture:
  - Image processing
- Announcements:
  - Discussion this week in UP B7 lab
  - Optional review sessions: T4:30-6 and W5:30-7, both in PHL 101. Attend one if you wish.
  - Prelim 2 on Thursday, 7:30-9pm



A picture as a matrix

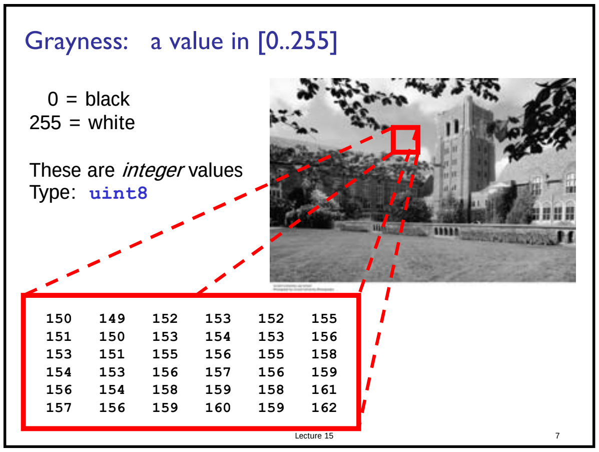
1458-by-2084

```
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)

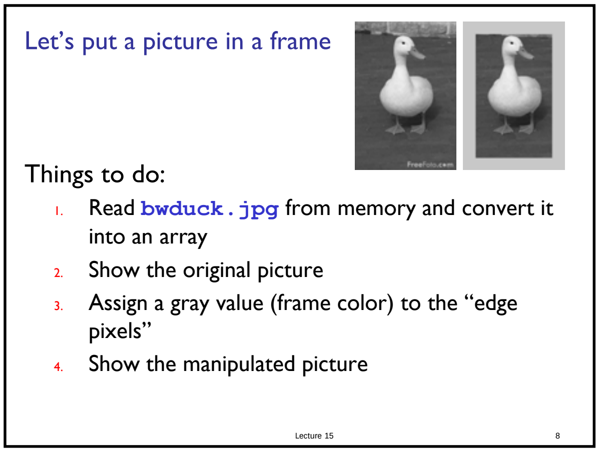


Grayness: a value in [0..255]

0 = black
255 = white

These are *integer* values
Type: `uint8`

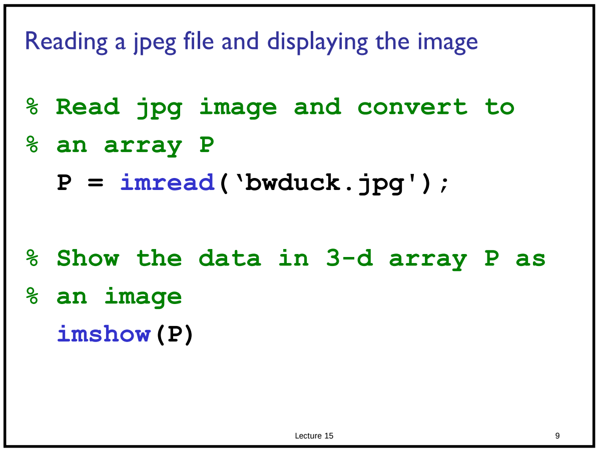
```
150   149   152   153   152   155
151   150   153   154   153   156
153   151   155   156   155   158
154   153   156   157   156   159
156   154   158   159   158   161
157   156   159   160   159   162
```



Let's put a picture in a frame

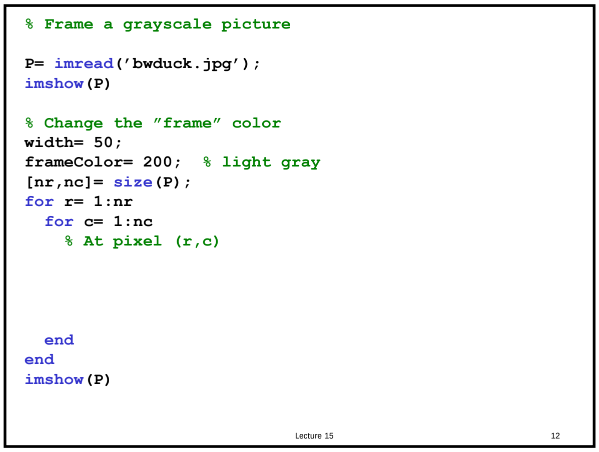
Things to do:

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

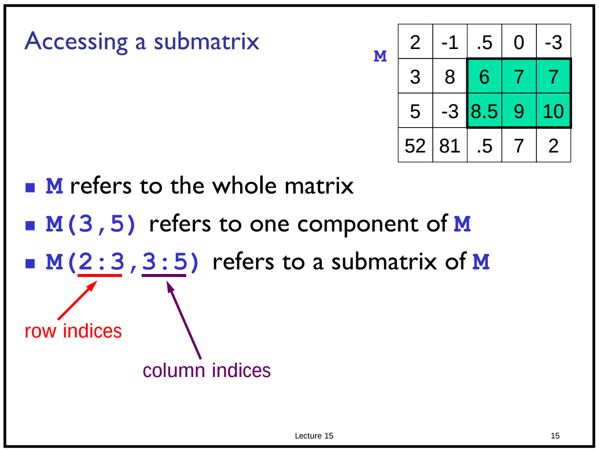


Reading a jpeg file and displaying the image

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

% Show the data in 3-d 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)
```

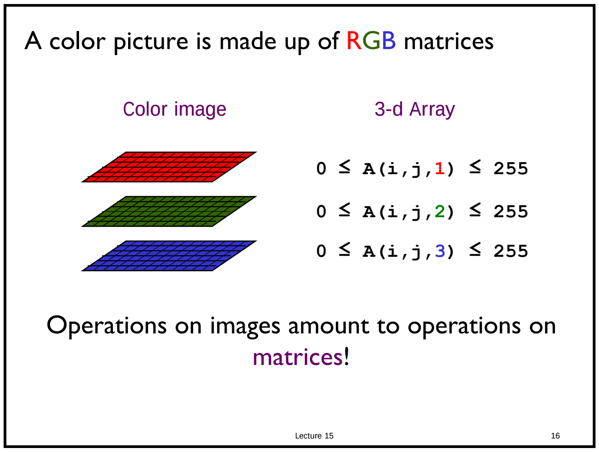


Accessing a submatrix

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`



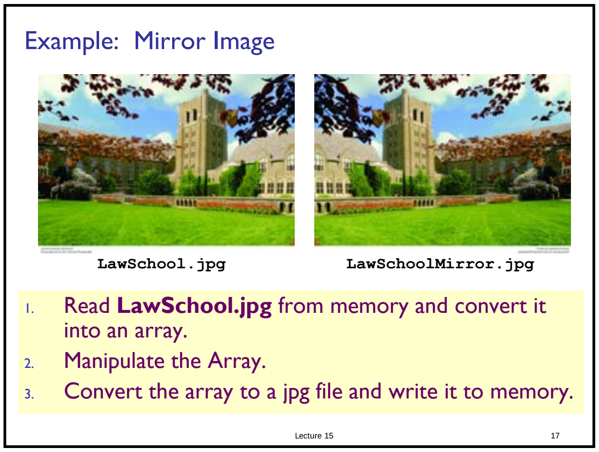
A color picture is made up of RGB matrices

0 ≤ `A(i,j,1)` ≤ 255

0 ≤ `A(i,j,2)` ≤ 255

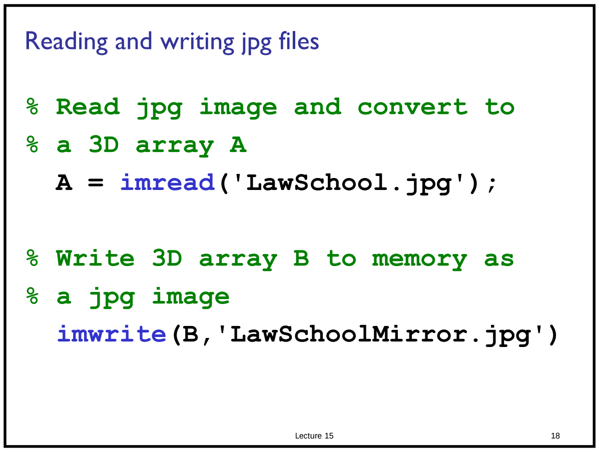
0 ≤ `A(i,j,3)` ≤ 255

Operations on images amount to operations on matrices!



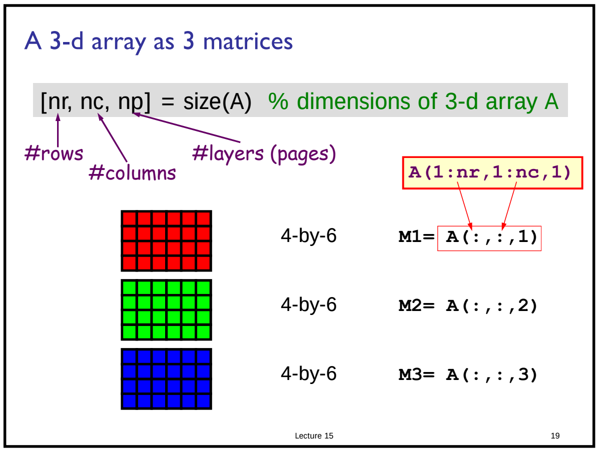
Example: Mirror Image

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

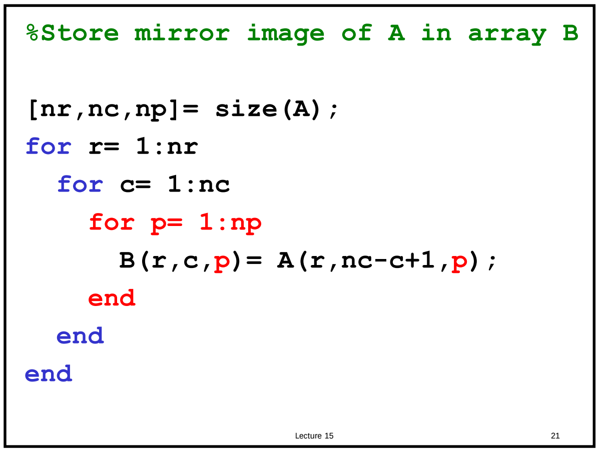
[nr, nc, np] = size(A) % dimensions of 3-d array A

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

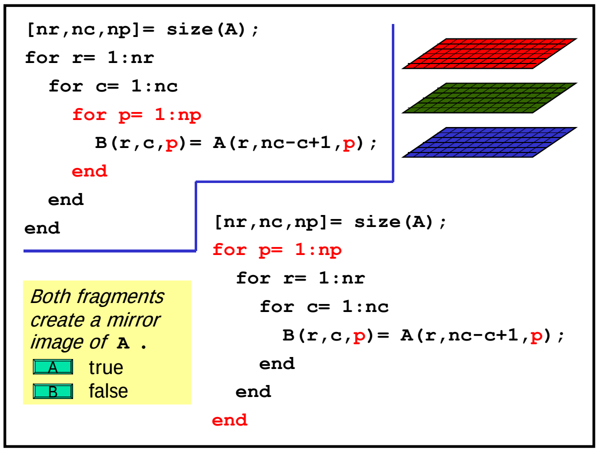
4-by-6 `M1= A(:,:,1)`

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



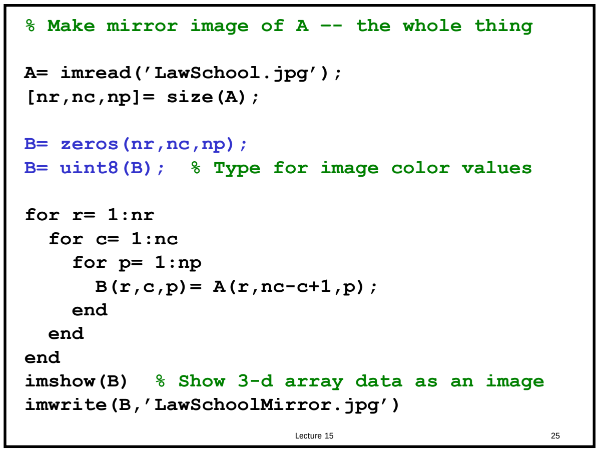
```
[nr,nc,np]= size(A);
for r= 1:nr
  for c= 1:nc
    for p= 1:np
      B(r,c,p)= A(r,nc-c+1,p);
    end
  end
end
```

```
[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
```

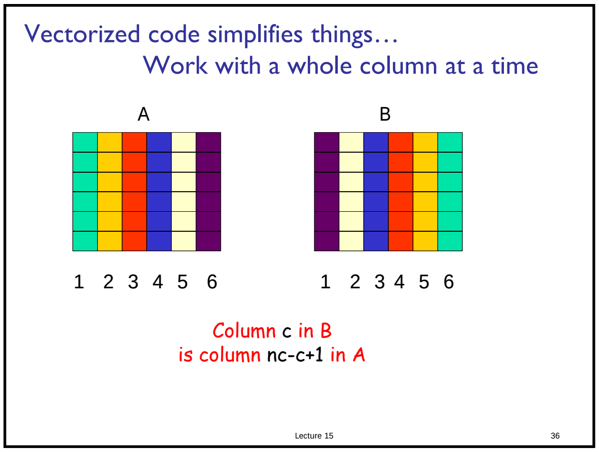
Both fragments create a mirror image of **A** .

A true

B false



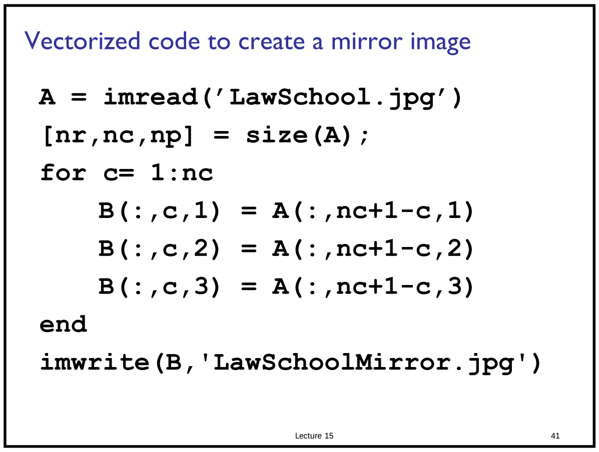
```
% Make mirror image of A -- the whole thing

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…

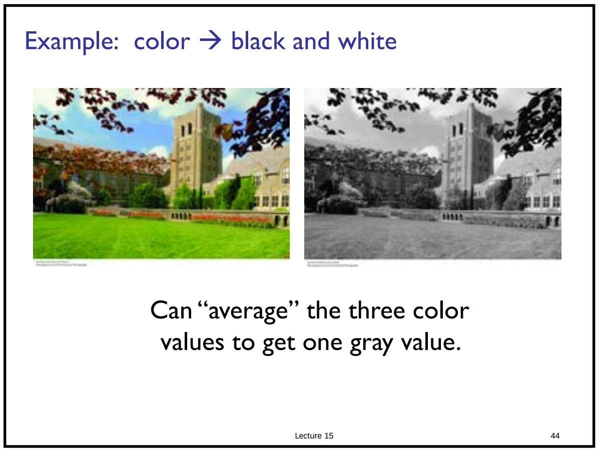
Work with a whole column at a time

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



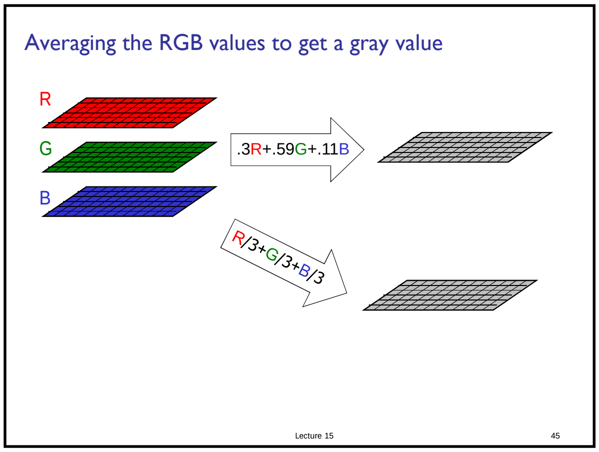
Vectorized code to create a mirror image

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



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

R

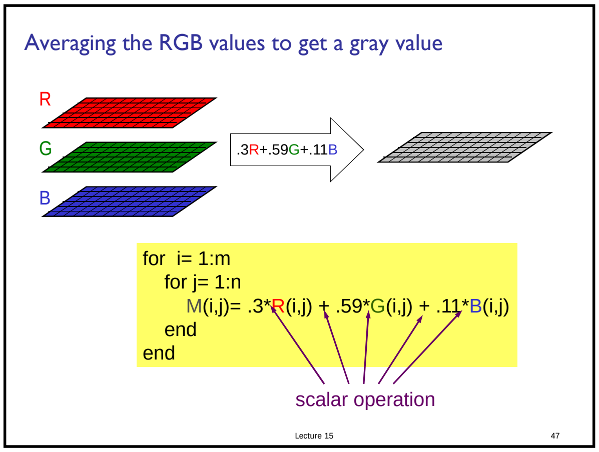
G

B

.3R+.59G+.11B

R/3+G/3+B/3

Lecture 15 45



Averaging the RGB values to get a gray value

R

G

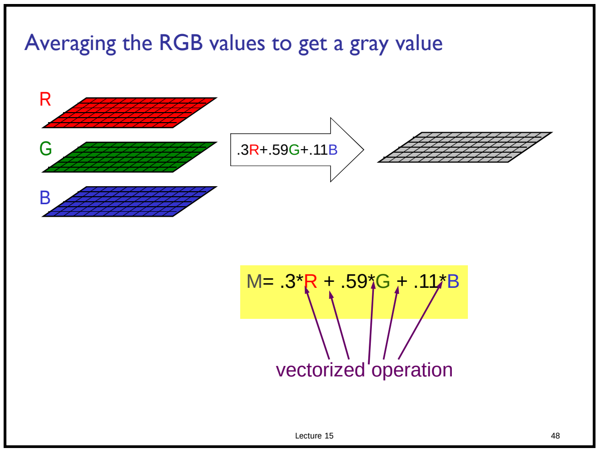
B

.3R+.59G+.11B

```
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

Lecture 15 47



Averaging the RGB values to get a gray value

R

G

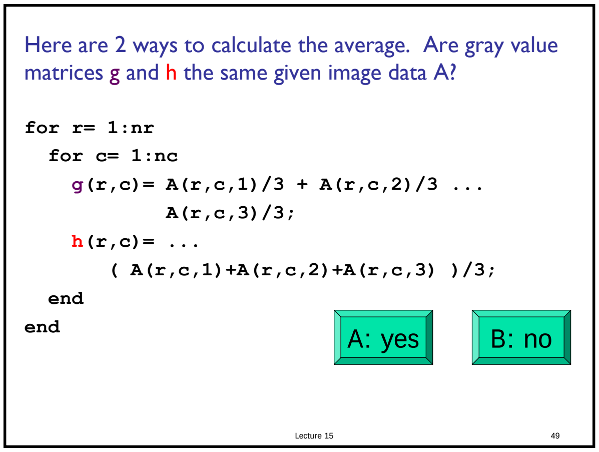
B

.3R+.59G+.11B

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

vectorized operation

Lecture 15 48



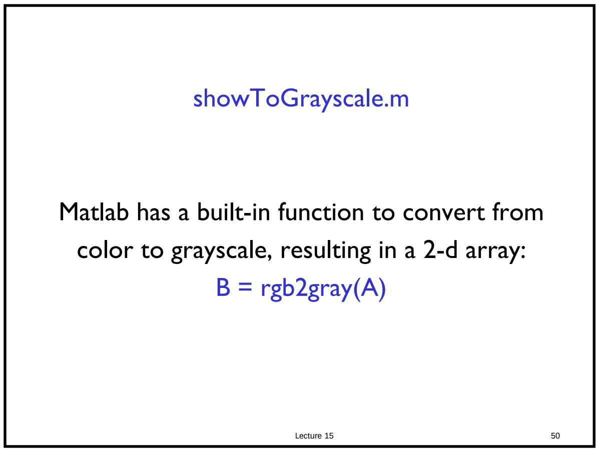
Here are 2 ways to calculate the average. Are gray value matrices g and h the same given image data A?

```
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

Lecture 15 49



showToGrayscale.m

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

B = rgb2gray(A)

Lecture 15 50